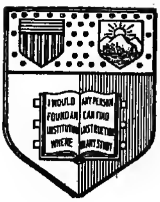
I WOULD FOUND AN INSTITUTION WHERE
ANY PERSON CAN FIND INSTRUCTION IN ANY STUDY

THE TECHNOLOGY OF BREAD-MAKING

INCLUDING

The Chemistry and Analytical and Practical Testing of Wheat Flour, and Other Materials Employed in Bread-Making and Confectionery.

By

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PREFACE.

THE intervention of war conditions has sadly interfered with the developments of this book, which the Authors had hoped to incorporate in a new edition.

In order to meet the insistent demands on the part of both bakers and millers for its reappearance it has been decided to issue a slightly abridged reprint of the previous edition, with certain corrections and additions rendered necessary by advances in knowledge during the past few years.

This has been rendered possible by the action of The Bakers' Helper Company, which has thrown itself into the breach at a time when the publication of a technical work is fraught with great difficulties and considerable risk. To that company in America, and The Northern Publishing Company, Limited, of Liverpool, well known as the proprietors of "MILLING," the Authors are indebted for the promise of every effort as publishers to bring the book to the notice of the milling and baking trades.

The Authors wish to make every acknowledgment, with their most sincere thanks, of the valuable help they have received from Miss Morris, of the staff of The Bakers' Helper Company, who has read the proofs and checked the passage of the book through the press in a most efficient manner.

WILLIAM JAGO.
WILLIAM C. JAGO.

Hove, England, 1921.

PREFACE TO 1911 EDITION.

THE volume now offered to the reader must be regarded as a development of the writers' former works on the same subject, which appeared in 1886 and 1895. The general mode of treatment is, therefore, to some extent governed by that of its predecessors. It should be remembered that the requirements of the student of the technology of bread-making, whether miller or baker, have been the first consideration; and accordingly the arrangement is that which seems most likely to be of service and assistance to him. In addition the authors have endeavoured to make the book as complete a work of general reference as possible.

In the preparation of the present treatise the writer has had the benefit of the assistance of his son, Mr. William C. Jago, whose name, together with his own, appears on the title-page. Mr. William C. Jago's wide experience of the practical application of chemical methods in the mill and the factory has been of much advantage. So also has been his knowledge of the dairying industries gained in Denmark, and of modern biology and bacteriology acquired in the laboratories of Professor Jorgensen in Copenhagen. The writer is further indebted to him for the investigation and verification of many references in the original French, German and Danish.

Since 1895 much valuable original work has been done in this country, and also in Europe and America, on bread-making and cognate subjects. The authors have tried to place this as fully as possible on record. In so doing they have adopted the method of giving a resume of each investigator's work and conclusions, following the same where necessary by any comments of their own. In pursuance of this plan, new chapters have been written on the Strength of Flour, the Bleaching of Flour, Wheat Flour and Bread Improvers, the Nutritive Value and Digestibility of Bread, and the Weighing of Bread. Subjects such as "Standard" Bread, and the use of additions to flour and bread, have been critically and exhaustively examined. The application of chemical and other tests to routine mill practice has been dealt with in a special chapter. Following on the inclusion of Confectionery in the programme of the City and Guilds of London Institute for the Advancement of Technical Education, a chapter has been added on the Chemistry of the Confectioners' Raw Materials and Processes.

Again, the Authors desire to express their thanks to the number of millers, bakers, and scientists who by personal communications and in many other ways have rendered them so much assistance in the preparation of this volume. The numerous instances of help of this kind will be evident on a perusal of the following pages.

In a work of such magnitude, the Authors cannot hope to have altogether avoided mistakes, and in such cases they confidently appeal to the generous consideration of their readers.

WILLIAM JAGO.

London, E.C.,
1, Garden Court, Temple,
July, 1911.

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THE TECHNOLOGY OF BREAD-MAKING

CHAPTER I.

INTRODUCTORY.

1. **General Scope of Work.**—The object of the present Work is to deal, in the first place, with those branches of knowledge which together constitute the scientific foundations of Bread-making as a science in itself. Paramount among these is—

Chemistry.

With which is closely associated—

Heat and its properties.
Fermentation and the Biology of Micro-organisms.
Vegetable Physiology in its relation to the Wheat Plant.
Microscopy.

Next, viewing Bread-making as an Art or Industry, the design of Bakeries and adaptation of Machinery for various purposes is discussed. Following on this is a description of the various processes and operations involved in the Commercial Manufacture of Bread, together with an investigation of the many important practical problems connected therewith.

The more purely analytical section of the work includes detailed directions for the commercial testing and valuation of flour, yeast, and other bread-making materials; in addition to which there are also given approved methods for the commercial and complete chemical analysis of such substances. A number of analyses and other chemical investigations have been recently made for the purpose of this book, and are here published. The work concludes with a description of the chemistry of confectioners' raw materials.

It is not proposed to adhere to any very rigid classification, but so to arrange the subject matter as seems most likely to meet the requirements of the majority of readers.

2. **Matter.**—The bodies with which we are surrounded present an almost endless diversity of colour, appearance, and other characteristics. One property they however all possess in common, and that is the property of *weight*. All bodies are attracted by the earth, and any substance is said to be heavy because of the resistance which it offers to this earth-attraction or gravitation. Not only are solid bodies, such as iron and wood, possessed of weight, but so likewise are liquids, such as water and oil, and also gases, such as, for example, common air, or coal gas. It is convenient to have one name for all bodies which possess weight, and for this purpose, in English, the term *Matter* is employed. **Matter, then, is anything which possesses weight (i.e., is acted on by gravitation), and exists in three distinct forms, namely, as solids, liquids, and gases.**

3. **Force.**—The definition of matter just given would seem at first sight sufficiently comprehensive to embrace everything of which we can take cognisance, but yet a moment's reflection shows the existence of other things besides matter. An illustration best demonstrates this fact—A hammer-head is known to consist of matter because it possesses weight; but if with this hammer-head you give a series of blows to a small piece of nail-rod, you have given the nail-rod something which is not matter. The hammer-head is not lighter, nor is the nail-rod heavier—still the blows are something, as otherwise they could produce no effect. For one thing, the nail-rod will have been flattened and altered in shape; further, and which is of far more present importance, it will have become hot to the touch. Again, to make use of another illustration, if a dry brick be carefully weighed and then made red-hot in a furnace, it will be found to weigh when hot precisely the same as it did when cold. Further, this brick, if allowed to become cold, imparts heat to surrounding objects, and nevertheless remains unaltered in weight. Here, then, is something very definite which a body can receive and again yield, and which is not matter. This something has, however, a very direct relation to matter; in the first illustration the blows were struck by the moving hammer-head, which consists of matter in motion. The more rapid the motion, the more violent would be the blows; in fact, the force of the blow depends both on the quantity of matter and the rapidity of its motion. A number of considerations lead to the belief that the hot iron of the nail-rod and also the hot brick differ from the same substances in the cold state, in that their component particles are in a state of movement; as these substances cool, the particles once more enter into a condition of comparative rest. This something beyond matter is closely associated with motion, and is termed force. **Force is defined as that which is capable of setting matter in motion, or of altering the direction or velocity of matter already in motion.** The motion of bodies may be divided into two classes: there is, first, that of the body as a whole, as in the case of the moving hammer-head; second, the internal movements of the particles of a body, as when it becomes hot.

Elements of Heat.

4. **Heat, its Nature and Effects.**—Among generally observed facts with regard to heat, one of the first and most important is that it induces the sensation of warmth. According to the character and degree of this sensation, a body is said to be cold, warm, or hot. The conditions which produce this sensation of warmth also cause other well-marked changes in the physical condition of substances. The general effects of heat are to cause bodies as they get hot to expand in volume; further, solids are reduced to the liquid state; and, with still further increments of heat, liquids are converted into gases. The opposite series of changes occur as heat is abstracted from bodies. From the explanation of Force given in the preceding paragraph, it will be understood that these changes are not accompanied by any addition or diminution of weight. On the contrary, **Heat is viewed as a form of Force, and is regarded as a mode or variety of internal motion of the particles of bodies—the hotter they are, the more violent and energetic is this motion.**

5. **Measurement of Heat: Temperature.**—The earliest and most accessible measure to be applied to heat is that of the sensation of warmth before referred to, and according to whether a body to the touch is hot or cold, it is said to be of high or low temperature. Temperature is, in

fact, the measure of what is popularly termed "how hot a body is"; it will be seen on consideration that this depends on the power the body has of imparting heat to another body. Thus if, when the hand is thrust into water, the water is able to yield heat to the hand, it is said to be "hot," while if it robs the hand of heat it is said to be "cold." The measure of this power is termed temperature, and is more exactly embodied in the following definition:—**The temperature of a body is a measure of the intensity of its heat, and is further defined as the thermal state of a body considered with reference to its power of communicating heat to other bodies.**

6. **The Thermometer.**—For scientific, and also for most technical, purposes, the sensations are not sufficiently accurate methods of measuring temperature; accordingly temperature is usually measured by certain of the effects which heat produces: the most convenient for this purpose is the expansion of liquids with an elevation of temperature. For the general purposes of temperature measurement, the metal mercury is the most convenient substance. This liquid, enclosed in a suitable vessel, constitutes the temperature-measuring instrument termed a thermometer. In constructing a thermometer, a bulb is blown at one end of a glass tube of very narrow bore; the bulb and tube are next filled with carefully purified mercury; this is boiled, and thus all air and moisture are driven out of the tube; the open end is then hermetically sealed by fusing the glass itself. At this stage the bulb and a portion of the tube are filled with mercury, the remainder of the tube being a vacuum, save for the presence of a minute quantity of mercury vapour. On heating the bulb of this instrument, the mercury expands and rises considerably in the stem. Throughout any body, or series of bodies in contact with each other, heat has a tendency so to distribute itself that the whole series shall be at the same temperature; consequently if the thermometer be placed in contact with the body whose temperature it is desired to measure, a redistribution of heat occurs, until the two are at the same temperature. That is to say, if the body be the hotter, it yields heat to the thermometer; and if it be colder, it receives heat from the thermometer, until the temperature of both is the same. The two being in efficient contact, this stage is indicated by the mercury becoming stationary in the thermometer. Now the volume of mercury is constant for any one temperature; therefore, to register temperature, it is only necessary to have further a scale, or series of graduations, attached to the stem of the instrument, by which the temperature may always be read.

7. **The Pyrometer.**—The ordinary mercury thermometer is not well adapted to the measurement of comparatively high temperatures, since the mercury boils at a temperature considerably below that of a dull red heat. In consequence other instruments have been devised for that purpose, to which the name of pyrometers has been given. The pyrometer may therefore be regarded as a high temperature thermometer. The pyrometers used for measuring the temperature of some types of bakers' ovens consist usually of a rod and casing constructed of materials which expand at different rates with an increase of temperature. The differential expansion actuates a needle moving in front of a dial plate.

8. **Thermometric Scales.**—Subject to certain precautions, the temperatures of melting ice and of steam in contact with boiling water are constant. The height at which the mercury stands when immersed in each of these is marked on most thermometers; for the registration of other temperatures some system of graduation must be devised. The one

most commonly employed in England is that of Fahrenheit, while for scientific purposes that of Celsius, or the Centigrade Scale, is almost universally adopted. Fahrenheit divided the distance between the melting and boiling points of his thermometer into 180 degrees; degrees of the same value were also set off on either side of these limits. At 32 degrees below the melting point he fixed an arbitrary zero of temperature from which he reckoned. On this thermometer scale, the melting point is 32°, while the boiling point is $32 + 180 = 212°$. Degrees below the zero are reckoned as — (minus) degrees, thus —8° means 8 degrees below zero, or 40 degrees below the melting point; degrees above 212 simply reckon upwards, 213, 214° F., etc.

The Centigrade Scale is much simpler, the melting point is taken as 0° or zero, and the boiling point as 100°; temperatures below the melting point are reckoned as — degrees.

The conversion from one to the other of the Centigrade and Fahrenheit Scales may be easily performed.

180 Fahrenheit degrees = 100 Centigrade degrees.
9 ,, ,, = 5 ,, ,,
1 ,, degree = 5/9 ,, degree.
9/5 ,, ,, = 1 ,, ,,

There is this important difference between the two scales—Centigrade degrees count from the melting point, while Fahrenheit degrees are reckoned from 32 below the melting point.

$$30° \text{ C.} = 30 \times 9/5 = 54 \text{ Fahrenheit degrees.}$$

Therefore 30° C. are equivalent to 54 Fahrenheit degrees above the melting point, but as the melting point is 32, that number must be added on to 54; temperature Fahrenheit equal to 30° C. is 86°. By the reverse operation, Fahrenheit degrees are converted into degrees Centigrade. The following formulæ represent the two operations:—

$$\frac{C°.\times 9}{5} + 32 = F°. \qquad \frac{(F°.-32)\times 5}{9} = C°.$$

The following table gives the equivalent readings on the two thermometric scales for some of the most important temperatures:—

—40° C. =	—40° F.	70° C. =	158° F.
—17.7 ,, =	0 ,,	75 ,, =	167 ,,
0 ,, =	32 ,,	80 ,, =	176 ,,
15 ,, =	59 ,,	85 ,, =	185 ,,
15.5 ,, =	60 ,,	90 ,, =	194 ,,
20 ,, =	68 ,,	93.3 ,, =	200 ,,
21.1 ,, =	70 ,,	95 ,, =	203 ,,
25 ,, =	77 ,,	100 ,, =	212 ,,
26.6 ,, =	80 ,,	150 ,, =	302 ,,
30 ,, =	86 ,,	200 ,, =	392 ,,
35 ,, =	95 ,,	232.2 ,, =	450 ,,
37.7 ,, =	100 ,,	250 ,, =	482 ,,
40 ,, =	104 ,,	260 ,, =	500 ,,
45 ,, =	113 ,,	287.7 ,, =	550 ,,
50 ,, =	122 ,,	300 ,, =	572 ,,
55 ,, =	131 ,,	316.6 ,, =	600 ,,
60 ,, =	140 ,,	350 ,, =	662 ,,
65 ,, =	149 ,,	400 ,, =	752 ,,

9, Quantity of Heat.—Temperature is not a measure of quantity of heat, for a thermometer would indicate the same temperature both in a vessel containing a pint, and one containing a gallon of boiling water, although it is evident that one must contain eight times as much heat as the other; further, to raise the gallon of water to the boiling point, eight times the amount of heat necessary to similarly raise the pint is required. This leads to the mode of measuring and registering *quantity* of heat. **Quantity of heat is measured by the amount necessary to raise a certain weight of some body from one to another fixed temperature. The amount of heat necessary to raise 1 gram of water from 0° to 1° C. is termed a Unit of Heat.** For the phrase Unit of Heat, a distinctive term, "**Calorie,**" is now frequently employed. From this it follows that to raise 2 grams of water from 0° to 1° C. will require 2 Units of heat, or 2 H.U., or 2 Calories. Between the freezing and the boiling points, *approximately* the same amount of heat is necessary to raise 1 gram of water through any 1 degree of temperature, so that to raise 1 gram through 2 degrees will require approximately 2 H.U. For practically all purposes, it may be taken that the weight of water in grams × degrees of temperature through which it must be raised = the number of H.U. or Calories required.

10. Specific Heat.—The quantity of heat necessary to raise the same weight of different substances through 1 degree of temperature varies very considerably. **The quantity of heat necessary to raise 1 gram of any substance through 1 degree of temperature is termed its Specific Heat.** From this definition it follows that the specific heat of water at 0° C. is 1.00, or unity. The following table gives the specific heat of various substances:—

Substance.	Specific Heat.
Water	1.00000
Alcohol	0.61500
Glass	0.19768
Iron	0.11379
Copper	0.09391
Mercury	0.03332

If equal weights of water at different temperatures are mixed together, the result is a mixture having a temperature the mean of the two; thus a gallon of water at 20° C. mixed with a gallon at 50° C. will produce a mixture at the temperature of 35° C. But if equal weights of two substances of different specific heats be thus mixed, the temperature of the mixture of the two will not be a mean of those of the substances, but will be nearer that of the substance having the higher specific heat. The most important mixture with which the baker has to do is that of flour with water, as the temperature of the resultant dough is a matter of vital concern to him. The results are complicated by the presence of other ingredients, as salt and yeast, and also in practice by loss of heat through absorption by the surroundings of the dough, and heat generated by chemical action among the ingredients. The following are the results of laboratory experiments made by mixing flour and water only, and carefully taking the temperatures, but not allowing for loss of heat absorbed by containing vessels.

Mixture		Result	Specific Heat.
500 grams of flour at	67° F.	= 1000 at 118° F.	0.53
500 ,, water at	145° F.		
500 ,, flour at	67° F.	= 1000 at 93° F.	0.42
500 ,, water at	104° F.		
500 ,, flour at	67° F.	= 1000 at 80.5° F.	0.40
500 ,, water at	86° F.		

The specific heats are calculated from the above experiments in the following manner:—in the first experiment 500 grams of water have fallen from 145° to 118°, that is 27°, during which they must have afforded 500 × 27 = 13,500 H.U. At the same time 500 grams of flour have been raised from 67° to 118°, that is through 51°, which is equal to 500 × 51 = 25,500 grams through 1°, and to do this 13,500 H. U. have been utilised; then to raise 1 gram through 1° there has been taken

$$\frac{13{,}500}{25{,}500} = 0{\cdot}53 \text{ H.U.}$$

therefore 0.53 is the specific heat of flour as derived from this experiment.

A number of observations have also been made on the temperatures of mixtures made in the bakehouse on the large scale for manufacturing purposes. The doughs were machine-mixed, and no allowance is made for the salt and compressed yeast, quantities of which were the same in all cases. The quantities, temperatures, and calculated specific heats are given in the following table:—

WATER.			FLOUR.		DOUGH.	FLOUR.
Quarts.	Lbs.	Temp.	Lbs.	Temp.	Temp.	Specific Heat.
53	132.5	95°	205	52.5°	79.0°	0.39
51	127.5	90°	205	50.0°	77.0°	0.30
51	127.5	90°	205	50.0°	77.0°	0.30
53	132.5	98°	205	53.0°	79.0°	0.45
53	132.5	89°	205	53.0°	76.0°	0.36
53	132.5	89°	205	53.0°	76.0°	0.36

The whole of these figures, it must be remembered, are those obtained in experiments made under conditions such as hold in the bakehouse, and represent rather the result of actual working, than theoretic specific heats with all disturbing causes eliminated. In the case of the mixtures made at the higher temperatures, there is naturally a greater loss of heat, and this causes an increase in the corresponding apparent specific heats. In consequence of this, the No. 1 Laboratory Experiment gives a remarkably high figure; but the whole of the others lie fairly closely together. Comparing those above given with a large number of observations on the manufacturing scale made, practically all the specific heat results range between 0.36 and 0.45, with a mean of 0.40, to which the majority approach most closely. Taking 0.40 as the working specific heat of flour, 1 unit by weight of water in falling through 1° raises 2.5 units by weight of flour through the same increment of temperature.

11. Sources of Heat.—Directly or indirectly all available terrestrial heat is practically derived from the sun: its immediate source, however, for manufacturing operations is the combustion of different kinds of fuel; these give out different amounts of heat according to their composition. The following table gives the number of heat units evolved by the combustion of one gram of each substance in oxygen:—

HEAT DEVELOPED DURING COMBUSTION.

Substance.	Formula.	Heat Units.
Hydrogen	H_2	34,462
Carbon	C	8,080
Carbon Monoxide	CO	2,634
Marsh Gas	CH_4	13,063
Olefiant Gas	C_2H_4	11,942
Alcohol	C_2H_5HO	6,909

HEAT DEVELOPED DURING COMBUSTION—*Continued.*

Substance.		Heat Units.
Welsh Coal	about	8,241
Newcastle Coal	„	8,220
Derbyshire Coal	„	7,773
Coke	„	7,000
Wood (dried in air)	„	3.547

12. Expansion by Heat.—It has already been mentioned that in most cases bodies expand under the influence of heat. Solids expand the least, and at a definite rate for each particular solid; liquids have a higher rate of expansion, each still having its own special rate; while gases expand at a far higher rate than either liquids or solids. The following table gives what are termed the

COEFFICIENTS OF LINEAR EXPANSION FOR 1° BETWEEN 0° AND 100° C.

Glass	0.000008613	Brass	0.000018782
Platinum	0.000008842	Lead	0.000028575
Iron	0.000012204	Zinc	0.000029417

These figures mean that each of these substances expands at the rate expressed by its own coefficient: thus 1 foot of glass at 0° C. becomes 1.000008613 feet long at 1° C., and so for each degree rise in temperature. When a body is heated, its whole three dimensions of course increase, and the coefficients of cubical expansion of solids for practical purposes, may be taken as three times their coefficients of linear expansion.

The apparent expansion of liquids is not so great as the real, because the vessels in which they are contained also expand. The following table gives the

TOTAL APPARENT EXPANSION OF LIQUIDS BETWEEN 0° AND 100° C.

Mercury	0.01543	Fixed Oils	0.08
Distilled Water	0.0466	Alcohol	0.116

The coefficient of apparent expansion for 1° C. is obtained by dividing these numbers by 100, thus that for mercury is 0.0001543. Mercury expands at a practically constant rate from 36° to 100° C.; water, however, contracts in rising from 0° to 4°, and then expands from 4° to 100° C.

13. Expansion and Contraction of Gases.—There are certain reasons which lead us to suppose that at a temperature of—273° C. bodies would be entirely devoid of heat. **This point—273° C. is therefore often termed the absolute zero of temperature; and temperature reckoned therefrom is termed "absolute temperature."** The absolute temperature of a body is its temperature in degrees C. + 273. All gases expand with increase, and contract with diminution, of temperature. The amount of expansion and contraction is the same for all gases between the same limits of temperature, provided the temperature is considerably higher than that at which they condense to liquids. **The volume of all gases is directly proportional to their absolute temperature.** Because of this variation with temperature **it is necessary to fix a temperature which shall be considered as a standard in expressing the volume of gas: 0° C. is commonly adopted for this purpose.**

Knowing the volume of a gas at any one temperature, its volume at any other may be easily calculated; thus, a vessel was found to contain 750 c.c. of air at 15° C.; it is required to find its volume at the standard temperature.

15° C. + 273 = 288° Absolute Temperature.
0° C. + 273 = 273° „ „

As 288 : 273 : : 750 : 711 c.c. of gas at standard temperature.

14. Relation of Pressure and Volume of Gases.—It is convenient here to note that the volume of a gas is also affected by the pressure to which it is subjected: this variation is governed by what is called Boyle and Marriotte's Law—**The volume of any gas is inversely proportional to the pressure to which it is subjected.** The most important variations of pressure to which gases are liable are those resulting from the changes in pressure of the atmosphere. The height of the mercury column of the barometer is a direct measure of the pressure of the atmosphere, therefore that pressure is commonly expressed in the number of millimetres (m.m.) which that column is high. **For purposes of comparison it is also necessary to reduce all pressures to one standard; that selected is an atmospheric pressure which causes the barometer to stand at 760 millimetres.**

The temperature and pressure quoted as standards for gas measurement 0° C. and 760 m.m. are often termed **normal temperature and pressure**; for this expression the abbreviation, "N. T. P," is frequently used.

The laws governing the relation between the volume and temperature and pressure of gases must not be regarded as absolutely exact, since they are subject to certain small but well-marked departures. These variations, however, have no direct bearing on the present subject.

15. Transmission of Heat.—It is well known that when one part of a body or place is heated, the other parts also become hot more or less quickly. Some explanation of how such transmission is effected must now be given. **There are three methods by which heat can be transmitted from one point to another, which are termed respectively Convection, Conduction, and Radiation.**

16. Convection.—As the word convection implies, a part or mass is heated by the heated matter being *conveyed* from one part to another. This kind of heating can only occur in liquids or gases where the particles of matter can move freely. One of the best illustrations of convection is the heating of an ordinary vessel of water by the placing of a fire underneath; the layer of water at the bottom first gets hot, and consequently expands and becomes of lower specific gravity. As a result of being lighter, it therefore rises to the surface, and its place is taken by other water which is colder and denser. This in its turn is heated and rises; continuous currents of warm water ascend through the liquid, and colder water descends to take its place. In this way the whole mass is gradually made hot. The heating of the water in a supply cistern on the top of a building by currents through flow and return pipes from a small boiler in the basement is due to convection. So, too, the ventilation of a building is naturally caused in the same way—heated air ascends and makes its way through exits at the highest point, while cold air enters through the joints of doors and windows or apertures specially provided for the purpose. Among other illustrations may be mentioned the warming of a building or room by hot-water pipes running close to the floor. The air is thereby heated and ascends; the cooler air falls and takes its place. Conversely, a mass of water or air is best cooled by the application of cold at the upper surface. Thus, given a vessel of hot water and a coil of pipes at the surface, through which cold water is passing, the cold water lowers the temperature of the upper layer in the vessel; this consequently descends and its place is taken by hotter water. In this way a series of currents is set up whereby the whole mass of water is uniformly cooled. It will be seen that **convection is a mode of distributing heat through a mass of either liquid or gas by means of moving currents, such currents being usually produced by differences in density due to expansion caused by the source of heat itself.**

17. Conduction.—Instances are well known in which the application of heat to any one point of a solid causes the whole mass to become hot. Thus, if the end of a bar of iron be placed in the fire, the other end gradually increases in temperature. This cannot be due to convection, but is due to the heating effect which the hot particles of the body have on the contiguous particles. In these cases the heat is said to be transmitted by conduction. **Conduction is that method of transmitting heat in which the heat passes from the hotter particles of a body to the colder ones lying in contact with them, and so throughout the whole body.**

There are wide differences in the power of conducting heat displayed by various substances; thus, if a bar of copper be heated in the same way as suggested for the iron, the further end becomes hot far more rapidly. If, instead, a rod of glass or porcelain be heated, the outer end gets hot only with extreme slowness. It must therefore be remembered that **some substances conduct heat much more rapidly than others.** The metals as a class are good conductors, although there are great differences between them. Porcelain, tiles, glass, and earthy substances are generally bad conductors, so also are most bodies of animal or vegetable origin, as, for example, felt, wool, and wood. Water is a bad conductor, and so are the gases. Air is one of the worst heat conductors known, consequently porous masses, as slag-wool and fossil earth, conduct very badly, not only from their own non-conducting power, but because of the air retained in their interstices. Owing to their very slight conducting properties, wool, glass, bricks, and similar bodies are frequently termed non-conductors. The following table gives the comparative conducting power of a few substances, silver being taken as 100.

COMPARATIVE POWERS OF CONDUCTIVITY.

Silver		100
Copper		75
Iron		10
Lead		8
Marble	about	2
Porcelain	„	1
Brick Earth	„	1

18. Radiation.—It has been already explained that when a substance is hot, its particles are in a state of motion: under circumstances in which transmission of heat by convection and conduction is impossible, one body may yet be heated by another. The explanation now generally accepted is, that all space is permeated by a highly elastic body to which the name of *ether* has been given, which is capable of being set in undulatory motion by appropriate agitation. The violently moving particles of a hot body in the act of vibration strike against this ether, setting up in it a series of waves. These waves spread in all directions, and on impingeing against a cold body, cause its particles also to assume a state of vibration—that is, they make the substance hot. **In this way heat passes from one body to the other, not, however, as hot matter, but as a peculiar wave-like**

motion in the substance called ether. This is known as "Radiation" of Heat, and is independent of the temperature of the medium through which radiation occurs.

Radiation occurs in straight lines in all directions from the body which is evolving heat, and follows the same general laws of reflection as those which govern light. At the same temperature different bodies radiate heat at different rates. The rate of radiation is affected both by the nature of the radiating material and also the condition of its surface, whether rough or smooth. Highly polished surfaces radiate less rapidly than those which are roughened. Being maintained at the same temperature, the following table gives the comparative radiating power of different bodies.

COMPARATIVE POWER OF RADIATION.

Lampblack (Soot)	100
White Lead	100
Tarnished Lead	45
Polished Iron	15
Burnished Silver	2.5

When hot, surfaces of clay and brick are good radiators of heat, so also are those of flannel and other like substances.

In order that bodies may be heated by radiant heat, it is necessary that they possess the power of absorbing such heat—like radiation, this power of absorption also varies with different bodies. Those which are good radiators of heat are good absorbents, and practically the table showing power of radiation equally applies to power of absorption.

A good illustration of the different modes of transmission of heat is furnished by the action of one of the pipes of a steam oven. This pipe contains a certain quantity of water sealed up in the pipe. The pipe is built into the oven on a slight incline so that the lower end is in the furnace, and the upper one in the baking chamber of the oven. The fire of the furnace or the heated gases thereby produced are in contact with the pipe. By *conduction* the heat finds its way through the iron walls of the pipe and into the water. This is heated by *convection* currents, and ultimately the steam finds its way into the upper parts of the pipe which are in the oven. The metal is consequently heated by conduction and by conduction the heat passes through to the outer surface. There it partly warms the air by a process of conduction and also sets up *radiation* by which anything placed in the oven to bake is in due course heated.

19. Mechanical Equivalent of Heat.—It has already been stated that heat is produced when mechanical work is absorbed by friction or percussion, as when nail-rod is heated by repeated blows of the hammer. Careful measurements have shown that **the work done by 1 lb. falling through 772 feet (or 772 ft.-lbs.), is capable of raising the temperature of 1 lb. of water 1° F.: this amount is therefore termed the Mechanical Equivalent of Heat.** From this the value in degrees Centigrade is easily calculated, being $^9/_5$ of 772=1390 ft.-lbs. of work to raise 1 lb. of water through 1° Centigrade,

INTRODUCTORY CHEMICAL PRINCIPLES.

20. Definition of Chemistry.—Chemistry has well been defined as that science which treats of the composition of matter, of changes produced therein by certain natural forces, and of the action and reaction of different kinds of matter on each other. It follows that the **Chemistry of Wheat, Flour, and Bread may be defined as that branch of the science which treats of the composition of these bodies, of the changes they undergo when subjected to the action of certain natural forces, and of the action and reaction of these and other kinds of matter on each other.**

21. Introductory Study Necessary.—An elementary course of study of the general principles of chemistry must precede that of any particular branch of the applied science. Such a course should include the preparation and properties of the commoner elements and their compounds, the principles of qualitative analysis, and the simpler laws governing chemical action and combination. For this purpose Jago's "Elementary Chemistry," and "Advanced Chemistry," published by Messrs. Longmans & Co., may be employed. For convenience of reference and in response to a widely expressed wish, a short description follows of the most important chemical laws, and also of such elements and compounds as are closely connected with the chemistry of wheat, flour, and bread. This brief account must not, however, be accepted as a substitute for a systematic course of study of elementary chemistry.

22. Indestructibility of Matter.—Chemical changes are often accompanied by very great alterations in the appearance and properties of the bodies involved; for example, when a candle is burned it almost entirely disappears, but although it no longer remains in the solid state, all its constituents exist as gases, and these weigh exactly the same as did the candle, *plus* the oxygen of the air with which they have combined. **Matter is indestructible, and, consequently, the same weight of material remains after any and every chemical change as there was before its commencement.**

23. Preliminary Definitions.—It is important that at the outset accurate and concise ideas are gained of the meaning of various chemical terms. Although matter assumes so many diversified forms, yet all bodies, on being subjected to chemical analysis, are found to consist of one or more of a class of about eighty substances, which are termed "elements."

An Element is a substance which has never been separated into two or more dissimilar substances.

Recent chemical researches go to show that some of the bodies now regarded as elements, may after all be composed of more than one substance. However interesting such investigations may be, they are not likely to have any bearing whatever on our present subject.

While the letters of the alphabet are few, the number of words which can be formed from them is practically infinite; so, in a somewhat similar fashion, from the comparatively small number of elements which constitute the "alphabet" of chemistry, there may be built up an immense number of chemical compounds.

A compound is a body produced by the union of two or more elements in definite proportions, and, consequently, is a substance which can be separated into two or more dissimilar bodies. Compounds differ in appearance and characteristics from their constituent elements.

The term "Mixture" is applied to a substance produced by the mere blending of two or more bodies, elements or compounds, in any proportion, without union. Each component of a mixture still retains its own properties, and separation may be effected by mechanical means.

24. List of Elements.—The following is a list of some of the more important elements, together with their symbols and other particulars:—

Name.	Symbol.	Combining or Atomic Weight.		Atomicity or Quantivalence.
		Old.	New.	
Aluminium	Al	27	26.9	IV
Barium	Ba	137	136.4	II
Boron	B	11	10.9	III
Bromine	Br	80	79.36	I
Calcium	Ca	40	39.8	II
Carbon	C	12	11.91	IV
Chlorine	Cl	35.5	35.18	I
Chromium	Cr	52	51.7	VI
Copper (Cuprum)	Cu	63	63.1	II
Fluorine	F	19	18.9	I
Hydrogen	H	1	1.0	I
Iodine	I	126	125.9	I
Iron (Ferrum)	Fe	56	55.6	VI
Lead (Plumbum)	Pb	205	205.35	IV
Magnesium	Mg	24	24.18	II
Manganese	Mn	55	54.6	VI
Mercury (Hydrargyrum)	Hg	199	198.5	II
Nitrogen	N	14	13.93	V
Oxygen	O	16	15.88	II
Phosphorus	P	31	30.77	V
Platinum	Pt	193	193.3	IV
Potassium	K	39	38.86	I
Silicon	Si	28	28.2	IV
Silver (Argentum)	Ag	107	107.12	I
Sodium (Natrium)	Na	23	22.88	I
Sulphur	S	32	31.83	VI
Tin (Stannum)	Sn	118	118.1	IV
Zinc	Zn	65	64.9	II

25. **Recently Discovered Elements.**—Considerable interest attaches to certain elements which have been comparatively recently discovered. Among these are argon and other allied elements which exist in the atmosphere, and radium, a constituent of pitch-blende. As none of these bodies has apparently a bearing on the chemistry of bread-making they are not dealt with in this work.

26. **Metals and Metalloids.**—The elements are divided into two groups, termed respectively "Metals," and "Metalloids" or non-metals. The non-metals are distinguished in the foregoing table by being printed in small capitals. The line of division between the two classes is not very marked, the one group gradually merging into the other. The metals, as a class, are opaque bodies, having a peculiar lustre known as metallic; they are usually good conductors of heat and electricity. Two of the elements, mercury and bromine, are liquid at ordinary temperatures, while hydrogen, oxygen, nitrogen, and chlorine are gaseous.

27. **Symbols and Formulæ.**—The symbols are abbreviations of the names of the elements, and, where practicable, consist of the first letter of the Latin names. When two or more elements have names commencing with the same letter, it becomes necessary to distinguish them from each other by restricting the initial letter to the most important element and selecting two letters as the symbol of each of the others. Thus, carbon and chlorine each commence with "C," that letter is chosen as the symbol of carbon, while that of chlorine is Cl.

As all compound bodies consist of elements united together, they may be conveniently expressed symbolically by placing side by side the symbols of the constituent elements; the symbol of a compound is termed its **formula.** Thus, common salt consists of chlorine and sodium; its formula is accordingly written, NaCl.

28. Further Uses of Symbols and Formulæ: law of chemical combination by weight.—Simply as abbreviations of the full names, symbols and formulæ are of great service; this, however, is but a small part of their significance and value to the chemist. Their further use may best be explained by reference to certain information gained by experiment. to which careful attention is requested. On analysis, it is found that 36.5 ounces of the substance known as hydrochloric acid consist of 1 ounce of hydrogen, combined with 35.5 ounces of chlorine; also, that in 58.5 ounces of common salt there are 35.5 ounces of chlorine to 23 of sodium. Taking water as another instance of a hydrogen compound, analysis shows that its composition may be expressed by the statement, that 18 ounces of water consist of 2 ounces of hydrogen combined with 16 ounces of oxygen. In the table given on page 12 there is a column headed "Combining or Atomic Weight"; on referring to this it will be found that the numbers opposite hydrogen, chlorine, sodium, and oxygen, are, respectively, 1, 35.5, 23, and 16, being (with one exception) identical with those that have just been given as the numbers obtained by analysis of the compounds under consideration. **It is possible to assign to every element a number, which number, or its multiple, shall represent the proportionate quantity by weight of that element which enters into any chemical compound. These numbers are termed the "Combining or Atomic Weights" of the elements, and are deduced from results obtained on actual analysis.** In addition to its use as an abbreviated title of any element, **the symbol represents the quantity of the element indicated by its combining weight**; where multiples of that quantity exist in a compound, the fact is expressed by placing a small figure after the symbol and slightly below the line. In the table of elements there are two columns of combining weights given, headed respectively "Old" and "New"; the second column gives those obtained as a result of the most recent research and which represent the most exact determinations as yet made. For most purposes, the weights given in the first column are sufficiently accurate.

As previously stated, the formula of sodium chloride is NaCl, and it contains 23 of sodium to 35.5 of chlorine. The formula of hydrochloric acid is HCl, and it contains 1 of hydrogen to 35.5 parts of chlorine. Water consists of 2 parts of hydrogen to 16 of oxygen; the fact that it contains twice the combining weight of hydrogen is expressed by writing the formula H_2O. Again, ammonia contains 3 parts by weight of hydrogen to 14 parts of nitrogen, consequently it has the formula, NH_3; the substance commonly termed carbonic acid gas consists of 32 parts, or twice the combining weight, of oxygen to 12 by weight of carbon, the formula is consequently CO_2. **The quantity of an element represented by its combining weight is termed "one combining proportion" of that element.**

29. Constitutional Formulæ.—In addition to simply showing the number of atoms of each element present, formulæ are frequently so written as to show the probable constitution of the resultant compounds; such formulæ are termed "Constitutional Formulæ."

30. Chemical Equations.—Chemical changes are most conveniently expressed by what are termed "chemical equations": these consist of the symbols and formulæ of the bodies participating, placed before the sign =, while those of the resultant bodies follow. As an instance it may be mentioned that, when a solution of potassium iodide is added to one of mercury chloride, potassium chloride and mercury iodide are produced. The equation representing this chemical action is written thus:—

$$\underset{\text{Potassium Iodide.}}{2KI} + \underset{\text{Mercury Chloride.}}{HgCl_2} = \underset{\text{Potassium Chloride.}}{2KCl} + \underset{\text{Mercury Iodide.}}{HgI_2}.$$

Having access to a table of combining weights, the chemist learns from this equation that two parts of potassium iodide, each containing one combining proportion of potassium weighing 39, and one of iodine weighing 126 together with one part of mercury chloride, containing one combining proportion of mercury weighing 199, and two of chlorine each weighing 35.5, together yield or produce two parts of potassium chloride, each consisting of one combining portion of potassium weighing 39, and one of chlorine weighing 35.5, and one part of mercury iodide, containing one combining proportion of mercury weighing 199, and two combining proportions of iodine each weighing 126. As no chemical change affects the weight of matter, the weight of the quantity of a compound, represented by its formula, must be the sum of that of the constituent elements: so, too, the weight of the bodies resulting from a chemical change must be the same as that of the bodies before the change, whatever it may be, had occurred. Although from a chemical equation and table of combining weights, it is possible to state what relative weight of each element is concerned in any chemical action, it must never be forgotten that **the combining weights were first determined by experiment and then the table compiled therefrom.** The statement of premise and deduction is, that hydrogen and chlorine have respectively the combining weights of 1 and 35.5 assigned to them, because analysis shows that they combine in those proportions: **not** that hydrogen and chlorine have as combining weights 1 and 35.5, and therefore they must combine in those proportions. The combining weights are simply a tabular expression of results obtained by practical analytic investigation.

31. Atoms and Molecules.—The fact that the quantity of every element which enters into combination is either a certain definite and unchangeable weight, or a multiple of that weight, led chemists to regard this weight of a combining proportion of an element as being in some way associated with its physical nature. The first step toward the explanation of this question is due to Dalton, who enunciated what is termed the Atomic Theory. He assumed that all matter is built up of extremely small particles, which are indivisible, and that when elements combine, it is between these particles that the act of union occurs. These ultimate particles of matter are termed "Atoms." The name "atom" is derived from the Greek, and signifies that which is indivisible. Atoms of the same element are supposed to be of the same size and weight. With the absolute weight of atoms the student of bread-making chemistry has but little to do: the principal point of importance for him is their relative weights compared with each other. For chemical purposes, **an atom may be defined as the smallest particle of an element which enters into, or is expelled from, a chemical compound. For the phrase, "combining proportion," hitherto used, the term "Atom" may be substituted; the combining weight then becomes the relative weight of the atom of each element compared with that of hydrogen, which, being the lightest, is taken as unity.** Though the atomic theory does not admit of absolute proof, yet it so amply and consistently explains all the phenomena of chemistry that its essential principles are universally recognised.

The little group of atoms represented by the formula of a compound is termed a "molecule." **A molecule is the smallest possible particle of a substance which can exist alone.** In the case of chemical compounds the molecule cannot be further subdivided, except by separation into the atoms of its constituent elements, or into two or more molecules of some simpler chemical compound or compounds. When elements are in the free or uncombined state, their atoms usually combine together to form elementary molecules: thus with oxygen, two atoms unite to form a molecule of oxygen; the formula of the oxygen molecule is written, O_2.

The molecules of the following elements contain two atoms:—hydrogen, chlorine, oxygen and nitrogen.

As all elements normally exist in the molecular state, it is frequently advisable to use equations in which the lowest quantity of any element present is a molecule. Thus, $H_2 + Cl_2 = 2HCl$, should be written as the equation representing the combination of hydrogen and chlorine, rather than $H + Cl = HCl$. This rule applies more especially to the gaseous elements, as their molecular constitution has been definitely ascertained. But in the case of the solid elements the number of atoms in the molecule is not so well-known and therefore such elements are usually written as so many single atoms, and not as molecules.

32. Avogadro's Law.—The fact that all gases, whether elementary or compound, expand and contract at the same rate, when subjected to variations of temperature and pressure, has an important bearing on their probable molecular constitution. Their similarity in this respect has led to the assumption expressed in the "Law of Avogadro":—"**Under similar conditions of temperature and pressure, equal volumes of all gases contain the same number of molecules.**" From this it follows, that at the same temperature and under the same pressure, the volume of any gaseous molecule is the same whatever may be the nature and composition of the gas. The density of a gas being known, its molecular weight is easily calculated. The density of a gas is the weight of any volume, compared with that of the same volume of hydrogen, measured at the same temperature and pressure, and taken as unity. It has already been stated that the molecule of hydrogen contains two atoms; its molecular weight, expressed in terms of its atomic weight, is consequently 2. **The molecular weight of any gas is the weight of that volume which occupies the same space as do two parts by weight of hydrogen**; or is identical with the number obtained by doubling the density. Similar conditions of temperature and pressure are always understood in speaking of the comparative weights of gases. Conversely, as the molecular weight is the sum of the weights of the constituent atoms, the density of a gas may be calculated from its formula. Thus, carbon dioxide gas has as its formula, CO_2; its molecular weight is $12 + (16 \times 2 =)\ 32 = 44$; the density is $\frac{44}{2} = 22$. Here again it must be remembered that the molecular weight is primarily determined from the density, and not the density from the molecular weight.

33. Absolute Weight of Hydrogen.—As hydrogen is taken as the unit of comparison for other gases, it is necessary that its absolute weight be determined with the greatest exactitude. Experiment has shown that **1 litre of hydrogen, at normal temperature and pressure, weighs 0.0896 gram; or 11.2 litres weigh 1 gram.** The student must make up his mind to remember this figure; to quote Hofmann, the fact that at 0° C. and 760 m.m. pressure, 1 litre of hydrogen weighs 0.0896 gram, should be impressed "as it were with a graving tool on the memory." **The weight in grams of a litre of any gas is its density × 0.0896.** Thus, the density of carbon dioxide gas is 22; the weight of a litre is $22 \times 0.0896 = 1.9712$ grams.

34. Laws of Chemical Combination by Volume.—Not only does chemical combination follow definite laws, so far as weight is concerned, but also equally definite laws govern the proportions by volume in the case of gaseous bodies. For example, experiment shows that one volume of hydrogen unites with one volume of chlorine to form two volumes of hydrochloric acid gas. So, too, two volumes of hydrogen unite with one volume of oxygen to form two volumes of water-gas (steam). Again, ammonia consists of three volumes of hydrogen, united with one of nitrogen, to form two volumes of ammonia. The reactions are expressed in the following equations:—

$$\underset{\text{Hydrogen.}}{H_2} + \underset{\text{Chlorine.}}{Cl_2} = \underset{\text{Hydrochloric Acid.}}{2HCl.}$$

$$\underset{\text{Hydrogen.}}{2H_2} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Water.}}{2H_2O.}$$

$$\underset{\text{Hydrogen.}}{3H_2} + \underset{\text{Nitrogen.}}{N_2} = \underset{\text{Ammonia.}}{2NH_3.}$$

It will be observed that in the first equation one molecule of hydrogen unites with one molecule of chlorine to form two molecules of hydrochloric acid: the application of Avogadro's Law, therefore, teaches that these elements will unite in equal quantities of one volume to form two volumes of hydrochloric acid. In the same way, **the proportions by volume in which chemical changes occur between gaseous bodies are always expressed in the equation, it being remembered that all gaseous molecules occupy the same space when measured at the same temperature and pressure.** The following is a useful method of writing such equations, when the object is to show the proportions by volume in a chemical change in which any gaseous body is involved.

$$\underset{\text{1 volume.}}{H_2} + \underset{\text{1 volume.}}{Cl_2} = \underset{\text{2 volumes.}}{2HCl.}$$

$$\underset{\text{2 volumes.}}{2H_2} + \underset{\text{1 volume.}}{O_2} = \underset{\text{2 volumes.}}{2H_2O.}$$

$$\underset{\text{3 volumes.}}{3H_2} + \underset{\text{1 volume.}}{N_2} = \underset{\text{2 volumes.}}{2NH_3.}$$

35. Acids, Bases, and Salts.—The name acid is a familiar one, because it is continually applied in everyday parlance to anything which is sour. A number of bodies possess this distinction in common; to the chemist, the sourness of an acid is but an accidental property, as, according to his definition of these bodies, substances are included as acids that are not sour to the taste. **An acid may be defined as a body which contains hydrogen, which hydrogen may be replaced by a metal (or group of elements equivalent to a metal), when presented to the acid in the form of an oxide or hydroxide (hydrate).** As a class, the acids are sour; they are also active chemical agents; most acids are characterised by the property of changing the colour of a solution of litmus, a naturally blue body, to a red tint. Oxygen is a constituent of most acids. These are termed "oxy-acids." A few in which it is absent are termed "hydracids." Hydrochloric acid, HCl, is an example of these bodies. Most of the oxy-acids are produced by the union of water with an oxide—thus, oxide of sulphur and water form sulphuric acid:—

$$\underset{\text{Sulphur Trioxide.}}{SO_3} + \underset{\text{Water.}}{H_2O} = \underset{\text{Sulphuric Acid.}}{H_2SO_4.}$$

The oxides, which by union with water form acids, are termed anhydrides, or anhydrous acids. They are usually non-metallic oxides, but sometimes consist of metals combined with a comparatively large number of atoms of oxygen.

A Base is a compound, usually an oxide or hydroxide, of a metal (or group of elements equivalent to a metal, which metal (or group of elements) is capable of replacing the hydrogen of an acid, when the two are placed in contact. The greater number of metallic oxides are bases. Bases, as well as acids, differ considerably in their chemical activity. Certain bases are characterised by being soluble in water, to which they impart a peculiar soapy feel. These bases are termed "alkalies," and possess the property of restoring the blue colour to reddened litmus. The most important alkalies are sodium hydroxide, NaHO, and potassium hydroxide, KHO. The bases, lime, CaO, baryta, BaO, and magnesia, MgO, are more or less soluble in water, and also turn reddened litmus blue. They, with SrO, constitute the group known as the "Alkaline Earths." Hydroxides are compounds of oxides with water, thus:—

$$\underset{\text{Sodium Oxide.}}{Na_2O} \quad + \quad \underset{\text{Water.}}{H_2O} \quad = \quad \underset{\text{Sodium Hydroxide.}}{2NaHO.}$$

When an acid and base react on each other, the body, produced by the replacement of the hydrogen of the acid by the metal of the base, is termed a Salt. Water is also produced during the reaction. When the acid and base which have thus reacted are both of something like the same degree of strength, the resultant salt is commonly without action on litmus; that is it does not affect the colour whether it be red or blue. The salt is then said to be neutral. For example, when sulphuric acid, a strong acid, acts on potassium hydroxide, a strong base, the resultant salt, potassium sulphate, has no action on litmus. But when the acid is strong and the base feeble, or *vice versa,* the resultant salt will be governed in its degree of neutrality by the predominant component. Thus when potassium hydroxide combines with carbonic acid (a weak acid) the salt, potassium carbonate, is strongly alkaline to litmus. That is, it vigorously restores the blue colour to litmus which has been reddened. The action of acid and base on each other is illustrated in the following equation:—

$$\underset{\text{Acid.}}{HCl} \quad + \quad \underset{\text{Base.}}{NaHO} \quad = \quad \underset{\text{Salt.}}{NaCl} \quad + \quad \underset{\text{Water.}}{H_2O.}$$

36. Compound Radicals.—At times a group of elements enters into the composition of a body, and performs functions very similar to those of an atom of an element. Such groups are not only found to form numbers of very definite compounds, but may be even transferred from one compound to another without undergoing decomposition. **Groups of atoms of different elements which possess a distinct individuality throughout a series of compounds, and behave therein as though they were elementary bodies, are termed "Compound Radicals."**

37. Quantivalence or Atomicity.—Referring back to the three compounds of hydrogen mentioned in paragraph 34, it will be observed that one atom each of chlorine, oxygen, and nitrogen, combines respectively with one, two and three atoms of hydrogen. If chlorine and oxygen compounds be classified and compared, it is found that oxygen in almost every instance combines with just double as many atoms of the other element as does chlorine. **The atom-combining power of elements varies—Quantivalence or Atomicity is the measure of that combining power.** Among the elements, hydrogen, sodium, and chlorine are characterised by the fact that one atom of each rarely combines with more than one atom of any other element. Their atomicity is unity, and as every other element forms a chemical compound with one or more of these, the atomicity of any element can usually be determined by observing with how many atoms of one of these three elements an atom of the element in question enters into combination. The atomicity of the different elements is given in the table included in paragraph 24. Elements with an atomicity of one are termed monads; of two, dyads; three, triads; four, tetrads; five, pentads; and of six, hexads. It is often convenient to express the atomicity of an element graphically. This is done by attaching a series of lines to the atom, according to its atomicity. These lines may be viewed as indicating the number of links or bonds with which the particular atom can combine with other atoms. Of the actual nature of the force which holds atoms together in chemical compounds, nothing can be here stated: the bonds must only be viewed as indications of the number of such units of atom-combining power. The following are examples of these graphic symbols:—

H—	Cl—	—O—	—B=	=C=
Hydrogen.	Chlorine.	Oxygen.	Boron.	Carbon.

The same two elements often form a series of two or more compounds with each other; under these circumstances the atomicity must vary. In the great majority of such compounds, the atomicity increases or diminishes by intervals of two—that is, the atomicity is either even or odd for an element throughout all its compounds. This is sometimes accounted for by the supposition that two of the bonds of an element may, by their union, mutually satisfy each other. This is not, however, invariably the case, as certain well-marked exceptions to this rule are known. The highest known atomicity of an element is termed its "absolute" atomicity; the atomicity in any particular compound is the "active" atomicity; the absolute, less the active, atomicity is the "latent" atomicity.

38. Basicity of Acids.—In order to form salts, different acids require different quantities of a base: the measure of this quantity is termed **the "basicity" of the acid. The basicity of an acid depends on the number of atoms of hydrogen it contains that may be replaced by the metal of a base.** In forming salts, one atom of hydrogen is replaced by one atom of a monad metal, two atoms of hydrogen by an atom of a dyad, and so on. In the case of acids which contain more than one atom of replaceable hydrogen, salts are sometimes formed in which a part only of the hydrogen is replaced; such salts are termed "acid" salts, while those in which the whole of the hydrogen is replaced are termed "normal" salts. The following are typical examples of acids and the corresponding salts:—

MONOBASIC ACID.	DIBASIC ACID.	TRIBASIC ACID.
HNO_3.	H_2SO_4.	H_3PO_4.
Nitric Acid.	Sulphuric Acid.	Phosphoric Acid.
$NaNO_3$.	Na_2SO_4.	Na_3PO_4.
Sodium Nitrate.	Sodium Sulphate.	Sodium Phosphate.
	$HNaSO_4$.	Na_2HPO_4.
	Acid Sodium Sulphate.	Disodic Hydrogen Phosphate.
$Ca(NO_3)_2$.	$CaSO_4$.	$Ca_3(PO_4)_2$.
Calcium Nitrate.	Calcium Sulphate.	Calcium Phosphate.

It is often convenient to view the acids in the light of their being compounds of the anhydrides with water: the corresponding salts may then be written as compounds of the bases with the anhydrides. This method is almost invariably employed when calculating the relative quantities of metals and acids in bodies when subjected to analysis. Subjoined are the formulæ, written in this manner, of the acids and salts previously given as examples:—

H_2O, N_2O_5. **Two Molecules of Nitric Acid.**	H_2O, SO_3. **Sulphuric Acid.**	$(H_2O)_3, P_2O_5$. **Two Molecules of Phosphoric Acid.**
Na_2O, N_2O_5. **Two Molecules of Sodium Nitrate.**	Na_2O, SO_3. **Sodium Sulphate.**	$(Na_2O)_3, P_2O_5$. **Two Molecules of Sodium Phosphate.**
	$Na_2O, H_2O, (SO_3)_2$. **Two Molecules of Acid Sodium Sulphate.**	$(Na_2O)_2H_2O, P_2O_5$. **Two Molecules of Disodic Hydrogen Phosphate.**
CaO, N_2O_5. **One Molecule of Calcium Nitrate.**	CaO, SO_3. **Calcium Sulphate.**	$(CaO)_3, P_2O_5$. **One Molecule of Calcium Phosphate.**

39. Chemical Calculations.—Most of the chemical calculations necessary in analytic work may be readily made by the help of chemical formulæ and equations, together with a table of combining weights. The following are illustrations of some of the most important of these calculations.

40. Percentage Composition from Formula.—Chemists usually express the results of analysis of a substance in parts per cent., so that in the case of a chemical compound it is often necessary to be able to calculate its chemical formula from the percentage composition; or conversely, the percentage composition from the formula. The latter operation, as being the simpler, shall be first explained. It is possible from the formula of any body to arrive at the molecular weight of the compound, and the relative weight present of each element. Thus, to find the percentage composition of acid sodium sulphate:—

The formula is

$$\begin{array}{l}\mathrm{Na}\quad\ \mathrm{H}\quad\ \ \mathrm{S}\qquad \mathrm{O}_4\\ 23+1+32+(16\times 4=)\ 64=120.\end{array}$$

From the combining weights, given beneath each element, with their sum at the end, it is seen that the molecule weighs 120, and contains 23 parts of sodium. Knowing that 120 parts contain 23, it is exceedingly easy to calculate the number of parts per 100, as the problem resolves itself into one of simple proportion:—

As 120 : 100 :: 23 : 19.17 per cent. of sodium.
As 120 : 100 :: 1 : 0.83 „ „ hydrogen.
As 120 : 100 :: 32 : 26.66 „ „ sulphur.
As 120 : 100 :: 64 : 53.33 „ „ oxygen.
99.99

Precisely the same method of calculation has been applied to the determination of the percentages of hydrogen, sulphur, and oxygen. As the results seldom work out to a terminated decimal, the added percentages usually amount to only 99.99; but by continuing the calculation, any additional number of 9's could be obtained, and as 0.9 recurring is equal to 1.0, so 99.9 recurring is equivalent to 100.00. As another example, let it be required to determine the percentage of base and anhydrous acid respectively in calcium phosphate. This salt is represented by—

$$\underbrace{\begin{array}{l}(\mathrm{Ca}\quad \mathrm{O}\quad)_3\\ (40+16=)56\times 3\end{array}}_{168} + \underbrace{\begin{array}{l}P_2\ \ O_5\\ 62+80\end{array}}_{142} = 310$$

The molecule, which weighs 310, contains 168 of lime (CaO) and 142 of phosphoric anhydride (P_2O_5), consequently

As 310 : 100 :: 168 : 54.19 per cent. of lime.
As 310 : 100 :: 142 : 45.81 „ „ phosphoric anhydride.
100.00

41. Formula from Percentage Composition.—Let the following represent the results of analysis of a body:—

Sodium	16.79 per cent.
Nitrogen	10.22 „
Hydrogen	3.65 „
Phosphorus	22.63 „
Oxygen	46.71 „
	100.00

As a first step toward obtaining the formula, divide the percentage of each element by its atomic weight; the result will be a series of numbers in the ratio of the number of atoms of each element—

$$\frac{16.79}{23} = 0.73 \text{ of Sodium.}$$
$$\frac{10.22}{14} = 0.73 \text{ of Nitrogen.}$$
$$\frac{3.65}{1} = 3.65 \text{ of Hydrogen.}$$
$$\frac{22.63}{31} = 0.73 \text{ of Phosphorus.}$$
$$\frac{46.71}{16} = 2.92 \text{ of Oxygen.}$$

It is next necessary to find the lowest series of whole numbers that correspond to these; such a series may be obtained by dividing each number by the lowest one of the series:—

$$\frac{0.73}{0.73} = 1 \text{ atom of Sodium.}$$
$$\frac{0.73}{0.73} = 1 \text{ atom of Nitrogen.}$$
$$\frac{3.65}{0.73} = 5 \text{ atoms of Hydrogen.}$$
$$\frac{0.73}{0.73} = 1 \text{ atom of Phosphorus.}$$
$$\frac{2.92}{0.73} = 4 \text{ atoms of Oxygen.}$$

The formula of the compound is, therefore, $NaNH_5PO_4$; its name is "hydrogen ammonium sodium phosphate." The formula obtained in this way is the simplest possible for the body in question: it is evident that the percentage composition would be the same if there were double or any other multiple of the number of atoms of each element in the molecule. Other considerations are taken into account in determining whether the correct molecular formula is really the simplest thus obtained, by calculation, from the percentage composition, or a multiple of the same. **Such simplest possible formula is termed an Empirical Formula.**

42. Calculations of Quantities.—An exceedingly common type of calculation is that in which it is required to know the quantities of one or more substances required to produce a certain quantity of another body. Thus, hydrogen is commonly obtained by the action of zinc on sulphuric acid; suppose that 10 grams of hydrogen are required for some operation: what weights respectively of zinc and sulphuric acid are necessary for the purpose? Here, again, the equation gives the relative weights of each element and compound participating in the reaction. In every such calculation it is absolutely necessary that the equation and combining weights be known; but granted these, no other difficulties arise beyond those which can be readily overcome by an intelligent application of the principles of proportion.

In the case in question the equation is:—

$$\begin{array}{ccccccc} Zn & + & H_2\,S\,O_4 & = & Zn\,S\,O_4 & + & H_2. \\ 65 & & \underbrace{2+32+64}_{98} & & \underbrace{65+32+64}_{161} & & 2. \\ \text{Zinc.} & & \text{Sulphuric Acid.} & & \text{Zinc Sulphate.} & & \text{Hydrogen.} \end{array}$$

To produce two parts by weight of hydrogen, 65 of zinc and 98 of sulphuric acid are required, then—

As 2 : 10 : : 65 : 325 grams of zinc required.
As 2 : 10 : : 98 : 490 „ „ sulphuric acid required.

Another instance may be given, in which not only weights but also volumes of gases have to be calculated. It is required to know how much carbon dioxide gas in cubic centimetres and in cubic inches is evolved by the fermentation of 28.35 grams (= 1 ounce) of pure cane sugar, the gas being measured at a temperature of 20° C. and 765 millimetres pressure; it being assumed that the whole of the sugar is resolved into alcohol and carbon dioxide. The chemical changes involved in this process may be represented by the following equations:—

$$\begin{array}{ccccc} C_{12}\,H_{22}\,O_{11} & + & H_2\,O & = & 2C_6\,H_{12}\,O_6. \\ \underbrace{144+22+176}_{342} & & \underbrace{2+16}_{18} & & \underbrace{72+12+96}_{2\times180=360} \\ \text{Cane Sugar.} & & \text{Water.} & & \text{Glucose.} \end{array}$$

In the first place one molecule, equalling 342 parts by weight of cane sugar, is converted into two molecules of glucose, each weighing 180, or the two weighing 360.

$$\begin{array}{ccccc} 2C_6\,H_{12}\,O_6 & = & 4C_2\,H_5\,H\;\;O & + & 4C\;\;O_2. \\ \underbrace{72+12+96}_{2\times180=360} & & \underbrace{24+5+1+16}_{4\times46=184} & & \underbrace{12+32}_{4\times44=176} \\ \text{Glucose.} & & \text{Alcohol.} & & \text{Carbon dioxide.} \end{array}$$

The two molecules of glucose, weighing 360, are next decomposed into four molecules of alcohol, having a total weight of 184; and four molecules of carbon dioxide, each weighing 44, and the whole 176. From 342 parts by weight of cane sugar, 176 parts by weight of carbon dioxide are produced; then—

As 342 : 28.35 : : 176 : 14.59 grams of carbon dioxide, yielded by 28.35 grams of cane sugar.

The next step is to determine what is the volume of 14.59 grams of carbon dioxide at N.T.P. The molecular weight of carbon dioxide being 44, its density must be 22; one litre of hydrogen weighs 0.0896 grams, and therefore 1 litre of carbon dioxide must weigh $0.0896 \times 22 = 1.9712$ grams; then—

$$\frac{14.59}{1.9712} = 7.401 \text{ litres at N.T.P.}$$

Applying the laws previously given by which the relations between the volume and temperature and pressure of a gas are governed; then—

$$\left.\begin{array}{l}\text{As } 273 : 293 :: 7.401 \\ \quad 765 : 760\end{array}\right\} = \frac{293 \times 760 \times 7.401}{273 \times 765}$$

$= 7.891$ litres at 20° C. and 765 m.m. pressure $= 7891$ cubic centimetres

$$\text{As } 16.39 \text{ c.c.} = 1 \text{ cubic inch, then}$$

$$\frac{7891}{16.39} = 481.7 \text{ cubic inches.}$$

28.35 grams or one ounce of cane sugar would yield, according to the question given, 7891 c.c. or 481.7 cubic inches of carbon dioxide gas at 20° C. and 765 m.m. pressure.

The weight of sugar necessary to yield a certain volume of gas would be calculated on the same principles; as an illustration, the reverse of the calculation just made is appended. Required to know the weight of cane sugar necessary to produce 481.7 cubic inches or 7891 cubic centimetres of carbon dioxide gas at 20° C. and 765 mm. pressure.

$$\frac{273 \times 765 \times 7891}{283 \times 760} = 7401 \text{ c.c. at N.T.P.} = 7.401 \text{ litres.}$$

$$7.401 \times 1.9712 = 14.59 \text{ grams of } CO_2.$$

As 176 : 14.59 :: 342 : 28.35 grams of cane sugar required.

43. Gaseous Diffusion.—It is a well-known fact that gases mix with each other with remarkable readiness. For instance, if in a large room a jar of chlorine is opened at the level of the floor, the presence of the gas may be detected by its powerful odour, within a few seconds, in every part of the room. The natural process by which the chlorine is thus disseminated through the air is termed "gaseous diffusion"; it takes place between gases, even though the heavier is at first at the lower level. In other words, a heavy gas will diffuse up into a superincumbent light gas, while the light gas will make its way downwards and mix with the heavier one. In this way different gases, when placed in the same space, rapidly produce of themselves an uniform mixture. This process of diffusion will also go on through a porous membrane, as, for example, a thin diaphragm of plaster of Paris or porous earthenware. Thus, if a vessel be divided into two parts by a thin partition of porous material, and the one half be filled with one gas and the other with another, they will be found after some time to have become thoroughly intermixed with each other. The rate of diffusion of all gases through such a diaphragm is not the same, but depends on their densities. **The rate of diffusion of gases is inversely as the square root of their density.** Thus, hydrogen and oxygen have respectively densities of 1 and 16; hydrogen diffuses four times as rapidly as does oxygen.

44. Solution.—When certain solid substances, of which salt is a convenient example, are added to water, the solid disappears, and is said to be dissolved. The liquid which has been used for dissolving the substance is said to be a **solvent,** the substance which is dissolved is called a **solute,** and the liquid which as a result contains the dissolved substance is termed a **solution.** Solutions may be prepared of gases, liquids and solids. **A liquid solution may be defined as a homogeneous or uniform liquid mixture of a gas, a liquid, or a solid with a liquid.** The act of solution is not in itself one of chemical combination between the dissolved substance and the solvent (although solution may be followed in addition by chemical combination). Thus when a solution of salt in water is heated, the water may be driven off and the whole of the salt recovered in an unchanged condition.

45. **Gaseous Solution.**—Gases vary very greatly in their degree of solubility in water. In the following table is given the volumes of each gas dissolved in 100 volumes of water, at the temperatures of 0° and 15° C. respectively—

	0°C.	15°C.
Hydrogen	2.15	1.91
Nitrogen	2.03	1.48
Oxygen	4.11	2.99
Chlorine	solid	23.68
Carbon dioxide	179.67	100.20
Sulphur dioxide	6886.1	4356.4
Hydrochloric acid	50590.0	45800.0
Ammonia	104960.0	72720.0

Comparatively small quantities of hydrogen, nitrogen, and oxygen are thus dissolved, but that of oxygen is sufficiently large to have most important results in the economy of nature. Carbon dioxide is much more soluble, water absorbing about its own volume at ordinary temperatures. The last mentioned gases are examples of extremely soluble gases; their various solutions have important applications in chemistry and the arts. It will be observed that all the gases mentioned are less soluble in water at 15° than at 0° C., and as the temperature is raised the solubility still further diminishes. Most gases may, in fact, be entirely expelled from water by the act of boiling. The *weight* of a gas dissolved by water is increased by pressure, and is governed by an interesting law, viz., that it is directly proportional to the pressure exerted. As the volume of a gas is in inverse ratio to the pressure, it follows that the *volume* of a gas dissolved by water is the same at all pressures. The so-called mineral or aerated waters are prepared by forcing carbon dioxide into the water under pressure. On the release of the pressure the gas escapes and causes the familiar effervescence. Most of the gases mentioned in the foregoing table are much more soluble in alcohol than in water; thus 100 volumes of alcohol at 15° C. dissolve 28 volumes of oxygen and 320 volumes of carbon dioxide respectively.

46. **Solution of Liquids.**—Some liquids on being placed together mix or are said to be "**miscible**" in all proportions; an example of these is found in alcohol and water. Others practically refuse altogether to mix, as, for example, water and oil. Others again are to a limited extent soluble in each other. One of the best illustrations of these is that of water and ether; if these be shaken together in about equal proportions and then allowed to stand, the ether being the lighter, separates out as a layer on the surface of the water. On examination, however, the ether will be found to have water dissolved in it to the extent of about 3 per cent.; and the water will have dissolved about 10 per cent. of ether. (As a matter of fact, oils and water are also very slightly soluble in each other, but the amount of oil so dissolved is so minute as to be a negligible quantity, while traces only of water are dissolved by oil.)

47. **Solution of Solids.**—Solids vary very greatly in their degree of solubility in water. Among the mineral salts, barium sulphate is almost absolutely insoluble; calcium sulphate is dissolved to the extent of 1 part in 700 parts of water; while at the other end of the scale 2 parts of crystallized magnesium sulphate are dissolved by 3 parts of water at ordinary temperatures. In the majority of instances the solubility of substances in water is increased by an elevation of temperature, but this is not an absolute rule. Lime, for example, is much more soluble in cold than in hot water. Salt is almost equally soluble in cold and hot water; at 0° C. water dissolves 35.5 per cent. of salt, and 41.2 per cent. at 109.5° C., the boiling point of the solution. Sugar, on the other hand, is soluble in about half its weight of cold water, and in boiling water in all proportions. In order to determine the solubility of any particular substance, it must be allowed to remain in contact with the solvent until the latter has dissolved as much as it possibly can, and leaves the excess in contact with the solution. Under such conditions, the solvent takes up a definite proportion of the dissolved body for each particular temperature.

A perfect solution is quite clear and free from any cloudiness, as the solid particles will have completely disappeared from sight. Any turbidity is caused by the presence of minute solid or liquid particles in suspension. It is incorrect, therefore, to speak of a mixture of a permanently solid substance with water in the form of a creamy mass as a solution. Similarly one does not *dissolve* yeast in water; one is simply broken down into an intimate admixture with the other. Water dissolves many of the mineral salts, but does not dissolve resins or fatty matters. The resinous bodies, of which shellac may be taken as an example, are soluble in alcohol; while fats may be readily dissolved by ether, chloroform, and light petroleum spirit. Water, on the other hand, dissolves certain gelatinous and gummy bodies, but such solutions have special characteristics to which further reference is made in the following paragraphs.

48. **Osmose and Dialysis.**—Liquids which are miscible with each other in somewhat the same way as gases, also undergo diffusion more or less rapidly. The laws governing diffusion of liquids are more complex than those affecting the diffusion of gases: not only gases, but also **liquids, are capable of diffusion through a porous diaphragm; such diffusion is termed "Osmose."** Some of the most remarkable and important phenomena of liquid diffusion are those exhibited by aqueous solutions of different substances. Thus, let a sort of drum-head be made by stretching and fastening a piece of bullock's bladder, or either animal parchment or vegetable parchment paper, over a cylinder of some impervious material, as glass or gutta percha. Float this in a vessel of pure water, and pour inside it a strong solution of common salt. The brine and the pure water will only be separated from each other by the thin membrane of bladder or other similar material. After the lapse of some hours it will be found that the solution of salt will have diffused out through the membrane until the liquid both outside and inside the floating vessel has the same strength. By repeatedly changing the water in the outer vessel, the whole of the salt might be removed from the solution within the cylinder. On the other hand, if a solution of gum arabic were placed within the parchment drum, and subjected to precisely the same treatment, the gum would be found incapable of diffusion through the membrane. If a mixture of brine and gum were placed in the cylinder

with parchment bottom, and then floated on the surface of water, the salt would diffuse out and the gum remain behind; in this manner a complete separation of the two might be effected. **The separation of bodies by their respective ability or inability, when dissolved, to diffuse through a porous membrane, is termed "Dialysis."**

49. **Crystalloids and Colloids.**—All bodies, soluble in water, are capable of being divided into two great classes, known respectively as "crystalloids" and "colloids." **Crystalloids are substances which, on changing from the liquid to the solid state, assume a crystalline form. Bodies are said to be crystalline when they consist of crystals, and for chemical purposes a crystal may be defined as matter which has spontaneously assumed during the act of solidification a definite geometric form. In crystals there is also a definite internal molecular arrangement related to the crystalline form by certain determinate laws.** Solutions of crystalline bodies are usually, but not invariably, free from any marked viscosity. Crystalline bodies are only soluble to a definite extent in water, the quantity dissolved depending more or less on the temperature, as has been already explained. **Jelly-like substances, as gum and gelatin, are termed "Colloids," and do not acquire a crystalline form when assuming the solid state.** The colloids form, when treated with water, sirupy, viscous, or jelly-like solutions. They may be said to be soluble in water in all proportions. Thus, if a few drops of water be added to a piece of dry gelatin, the water will be absorbed by the gelatin, and after a time will be uniformly diffused throughout the whole mass. Successive portions of water may thus be absorbed by the gelatin, which will become gradually softer, assuming the consistency of a jelly; further addition of water produces a solution with more or less viscosity, depending on the degree of concentration. **Crystalloids are especially susceptible of dialysis; colloids exhibit under similar treatment very little tendency to pass through a porous membrane.** The probable reason for this inability on the part of colloids is that their solution particles are too large to readily pass through the interstices in the porous membrane. The membranes used for dialysis consist of colloid substances: gelatin in the jelly-like form at times is a very convenient dialysing agent. The apparatus used for the purpose of effecting dialysis is termed a dialyser. The phenomena of liquid diffusion have an exceedingly important bearing on many chemical changes which occur during bread-making.

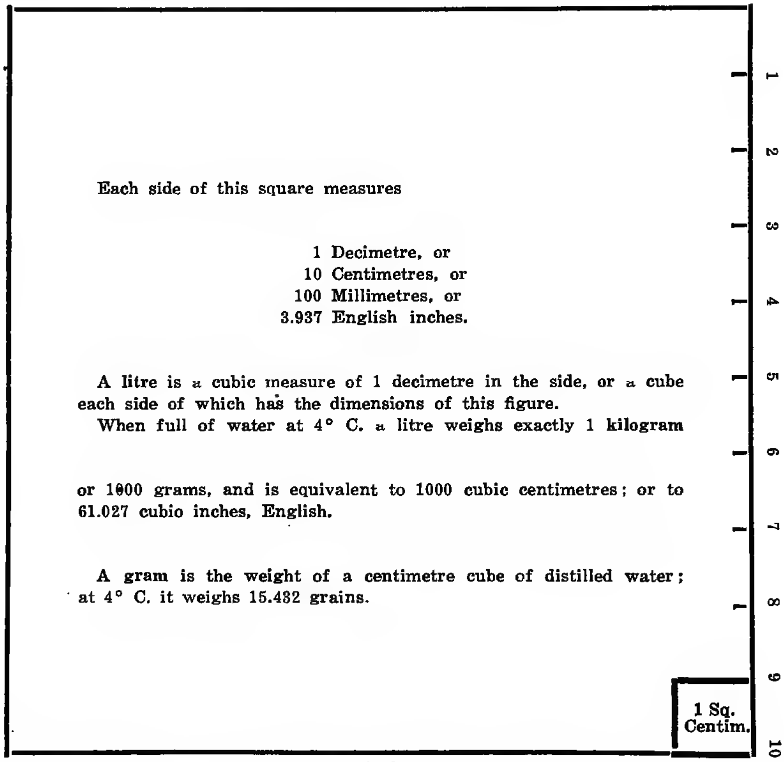
50. **Measures of Weight and Volume.**—It will be here convenient to furnish a statement of the different systems of weights and measures usually employed for scientific purposes. The chemist, as a rule, prefers the metric system, as in common use in France, to the very complicated system of weights and measures employed in this country. One reason is that the metric system is extremely simple; another, that the measures of weight and volume are directly connected with each other. If the authors simply followed their own predilections, metric weights and measures only would be used throughout this work, but it having been strongly represented to them that the introduction of the English equivalents of the different weights employed would be a help to some of their readers, they also have been, in most cases, given. The authors are conscious that the result of this intermixture is often incongruous, but to those familiar with the metric system this will present no difficulty, while to those who are unacquainted with it, it will be an assistance. It is nevertheless urged that the metric system be mastered; this may be easily done in a

quarter of an hour; much time will then be saved which otherwise would have to be spent in making calculations.

51. The Metric System.—The unit of the metric system is a "metre," which is the length of a rod of platinum that is deposited in the archives of France. The metre measures 39.37 English inches. The higher and lower measures are obtained by multiplying and dividing by 10, thus:—

Kilometre	=	1000	metres	=	39370	inches.
Hectometre	=	100	„	=	3937	„
Decametre	=	10	„	=	393.7	„
Metre	=				39.37	„
Decimetre	=	0.1	metre	=	3.937	„
Centimetre	=	0.01	„	=	0.3937	inch.
Millimetre	=	0.001	„	=	0.03937	„

In the above, and all other measures of the metric system, the prefixes "kilo, hecto, and deca" are used to represent 1000, 100, and 10 respectively; and "deci, centi, and milli," to represent a tenth, hundredth, and thousandth. The decimetre is very nearly 4 inches in length, and the millimetre very nearly one twenty-fifth of an inch: remembering this, measures of the one denomination can be roughly translated into those of the other. The exact length of a decimetre is shown in Fig. 1.



Each side of this square measures

1 Decimetre, or
10 Centimetres, or
100 Millimetres, or
3.937 English inches.

A litre is a cubic measure of 1 decimetre in the side, or a cube each side of which has the dimensions of this figure.
When full of water at 4° C. a litre weighs exactly 1 kilogram or 1000 grams, and is equivalent to 1000 cubic centimetres; or to 61.027 cubic inches, English.

A gram is the weight of a centimetre cube of distilled water; at 4° C. it weighs 15.432 grains.

FIG. 1.

The unit of the measure of capacity is the "litre," which is the volume of a cubic decimetre.

		Cubic Inches.	Pints.	Fluid Ounces.
Kilolitre	= 1000 litres =	61027	1760.7	35214
Hectolitre	= 100 „ =	6102.7	176.07	3521.4
Decalitre	= 10 „ =	610.27	17.607	352.14
Litre	=	61.027	1.7607	35.214
Decilitre	= 0.1 litre =	6.1027	0.17607	3.5214
Centilitre	= 0.01 „ =	0.61027	0.017607	0.3521
Millilitre	= 0.001 „ =	0.06102	0.00176	0.0352

The decimetre being 10 centimetres in length, it follows that a cubic decimetre must be equal to 1000 cubic centimetres, and that the millilitre has a volume of a cubic centimetre. The name "cubic centimetre," or its abbreviation "c.c.," is almost always used in preference to millilitre; thus, a burette or pipette is said to deliver 50 c.c., while a litre measure is often termed a "1000 c.c." measure.

A cubic inch is equal to 16.38 cubic centimetres.

The unit of the measure of weight is the "gramme," or "gram"; this is the weight of a cubic centimetre of distilled water at its maximum density (4° C. = 39.2° F.) :—

		Grains.	Avoirdupois Ounces.
Kilogram	= 1000 grams =	15432.3	35.2739
Hectogram	= 100 „ =	1543.23	3.52739
Decagram	= 10 „ =	154.323	0.35273
Gram	=	15.4323	0.03527
Decigram	= 0.1 gram =	1.54323	0.00352
Centigram	= 0.01 „ =	0.15432	0.00035
Milligram	= 0.001 „ =	0.01543	0.000035

A kilogram is just over 2 lb. 3¼ oz., and a hectogram is very nearly 3½ oz. An ounce avoirdupois equals 28.35 grams, and 1 lb., 453.6 grams.

The relation between the weight and volume of water is a very simple one, the volume being the same number of c.c. as the weight is grams. With other liquids the volume in c.c. × specific gravity = weight in grams.

52. English Weights and Measures.—Familiarity with English weights and measures is assumed, still the following particulars will most likely be of service—one gallon of pure water at a temperature of 62° F. (16.6° C.) weighs 10 pounds or 160 ounces or 70,000 grains; the pint, therefore, weighs 20 ounces. The measure termed a "fluid ounce" is derived from the weight of a pint of water. A fluid ounce is a measure of volume, not of weight, and equals one-twentieth part of a pint. The fluid ounce bears the same relation to the avoirdupois ounce as does the cubic centimetre to the gram. A gallon is equal to 277.274 cubic inches. An ounce avoirdupois weighs 437.5 grains.

53. Specific Gravity.—The same volume of different substances varies considerably in weight. Water is commonly taken as the unit of gravity for the purpose of stating that of other liquids and of solids. The specific gravity of any liquid or solid is the weight of that volume which in the case of water at a standard temperature and pressure weighs 1 unit. Thus the cubic centimetre of water weighs 1 gram, the cubic centimetre of mercury weighs 13.59 grams, and 13.59 is accordingly said to be the specific gravity of mercury. At times the specific gravity of water is taken as 1000 instead of 1; this is convenient in the case of bodies which are lighter than water. The specific gravity multiplied by 10 gives the weight of a gallon of any liquid. Thus alcohol and milk have respectively the specific gravities of 0.79350 and about 1.030. The gallon of each would weigh 7.935 and 10.30 lbs.

CHAPTER II.

DESCRIPTION OF THE PRINCIPAL CHEMICAL ELEMENTS AND THEIR INORGANIC COMPOUNDS.

54. **Description of Elements and Compounds.**—It is intended in this chapter to give a very brief description of those elements and their inorganic compounds, which are more or less directly connected with the chemistry of wheat, flour, and bread, and to which reference may be made in the latter part of this work. Such descriptions as are here given must not be viewed as being in any way a substitute for a careful study of elementary chemistry. It is thought, however, that to many readers, more particularly those who may not have the time for such a systematic course, an account such as is to follow will be found of service.

55. **Hydrogen, H_2.**—This element is a gas, and is the lightest substance known; it is consequently selected as the standard by which the density of other gases is measured. One litre of hydrogen at N.T.P. weighs 0.0896 gram. Hydrogen has the lowest atomic weight of all the elements, and is therefore also selected as the unit of the modern system of atomic or combining weights. (For certain reasons, the atomic weights are sometimes calculated to the basis of 16.00 as the atomic weight of oxygen.) Hydrogen is colourless, odourless, tasteless, and non-poisonous. It is not capable of supporting respiration, and therefore animals placed therein quickly die through lack of proper air to breathe. Hydrogen is inflammable and burns with a pale blue flame; it does not support combustion. Hydrogen is only very slightly soluble in water.

56. **Oxygen, O_2.**—This element is a colourless, odourless, and non-inflammable gas. Its most remarkable feature is that it supports combustion and also respiration. Bodies which burn in ordinary air do so because that substance is a mixture of oxygen and nitrogen; they burn with much increased brilliancy in oxygen. The respiration or breathing of animals consists of a removal of oxygen from the air, and a return thereto of water vapour and carbon dioxide gas: the activity of oxygen renders it injurious to breathe in a pure state: in air, the nitrogen acts as a diluting agent, without modifying the essential characteristics of the gas. Oxygen is soluble in water to the extent of three volumes of the gas in one hundred volumes of water at 15° C. This quantity, though small, is of vast importance, as it thus supports the life of fishes, and has also a most important action on fermentation. Although oxygen is such an essential to most forms of life, there are some of the lower microscopic organisms towards which it acts as a most energetic poison. Compounds produced by the union of elements with oxygen are termed "oxides."

57. **Ozone, O_3.**—This body is a gaseous substance consisting of pure oxygen, but having a density of 24 instead of 16. This is due to there being 3 atoms of the element in the molecule, instead of 2 as in ordinary oxygen. Ozone has a peculiar odour; and is produced during the working of a frictional electric machine, when its smell is recognized. Traces

of this gas exist in the air in mountainous districts, and by the seaside. By exposure to a temperature of 237° C. ozone is transformed into ordinary oxygen. Ozone is a powerful oxidizing agent, and is inimical to the growth and development of germ life. Ozone has been proposed as a bleaching agent for flour; its employment for that purpose will be discussed in full at a later stage.

58. Water, H_2O.—This most important compound consists of two volumes of hydrogen united to one volume of oxygen, to form two volumes of water-gas or steam. By weight, water contains 16 parts of oxygen to 2 of hydrogen. Water in the pure state is odourless and tasteless; viewed through thick layers it has a blue colour. At temperatures below O°C. water exists in the solid state; on being heated, ice expands until a temperature of O° C. is reached. At this point the ice begins to melt; the temperature remains stationary until the whole of the ice is melted, but in order to effect the change from the solid to the liquid condition as much heat is required as would be sufficient to raise 79 times the weight of water from 0° to 1° C. Ice in melting contracts in bulk; 10.9 volumes of ice producing 10 volumes of water. As the ice-cold water is further heated, contraction continues until a temperature of 4° C. is reached: at this point water is at its maximum density, and any given weight of it occupies its minimum volume. With further application of heat the water expands, and also rises steadily in temperature. In metal vessels open to the air, water boils at a temperature of 100° C. Continued heating now converts the whole of the water into steam, but does not raise the temperature. The quantity of heat necessary to convert the whole of the water at 100° C. into steam at the same temperature would raise 537.2 times the weight of water from 0° to 1° C. Steam in being further heated expands, and may have its temperature raised indefinitely; steam follows the same law of expansion on increase of temperature as do other gases. Steam, on being cooled, passes through a series of changes which are the exact converse of those just described. At all temperatures water gives off vapour, but with much greater rapidity as the temperature approaches the boiling point. This vapour exerts a definite pressure, the pressure increasing steadily with the temperature; at the boiling point, the pressure exerted by the vapour of water is exactly equal to that of the atmosphere; consequently, if the atmospheric pressure be diminished, the boiling point of water, and also that of all other liquids, is lowered. Advantage is taken of this property in many operations in the arts; thus, in driving off the water from sugar solutions, as in the preparation of malt extract, the boiling is effected in a vacuum, and so the temperature prevented from rising to any great height. On the other hand, by subjecting water to pressure, its boiling point may be raised to any temperature attainable, the only limit being the capacity, for resisting the pressure, of the material of the vessel. The tubes of steam ovens are constructed on this principle—a certain quantity of water is sealed up in them, which, on being heated, is converted into steam having a sufficiently high temperature to effect the baking of bread. The boiling point of water also depends on any substances it may have in solution. Salt and other non-volatile bodies raise the temperature of the boiling point, but do not affect that of the steam produced, which immediately falls to 100° C. Admixture of volatile bodies lowers the boiling point; thus, a mixture of water and alcohol boils at a temperature below 100° C. until the whole of the alcohol has been expelled.

59. Solvent Power of Water.—Water is, of all bodies, pre-eminently *the* solvent in nature. As a result of this property, water is never found in a state of purity in nature. Even rain is found to have dissolved out traces of solid matter that were suspended in the air, while river and spring water is always more or less impure from saline and other matter dissolved from the soil and rocky strata from whence it is obtained. In addition to the solid matter there is also invariably more or less gas held in solution in natural waters. A further account of natural waters, having particular reference to their fitness for bread-making, is given in a future chapter. For chemical purposes all such water is purified by distillation, that is, it is converted into steam, and re-condensed; the solid impurities then remain behind. This treatment does not, however, free the water from gases or from volatile impurities. For certain purposes, where rigidly pure water is a necessity, special modes of preparation have to be adopted; these will be described in detail hereafter.

60. Hydrogen Peroxide, H_2O_2.—In addition to water, there is also known a higher oxide of hydrogen, to which the name of hydrogen peroxide is given. In the pure state, hydrogen peroxide is a colourless, odourless, and somewhat sirupy liquid having a peculiar metallic taste. It is extremely unstable, readily giving off oxygen, and leaving a residue of pure water. When diluted with water, hydrogen peroxide is much more stable, and this stability is increased by the addition of a small quantity of acid. But on heating, this solution is changed into water and free oxygen. This readiness to give up oxygen causes the peroxide to be a powerful oxidizing agent, and as such it possesses active bleaching properties. The semi-molecule of hydrogen peroxide, HO, enters into the composition of a large number of compounds, and has received a specific name, hydroxyl.

61. Chlorine, Cl_2.—This element is, at ordinary temperatures, a gas of a greenish yellow colour, with a most pungent, acrid, and suffocating odour and taste. The presence of comparatively small quantities renders air irrespirable. Chlorine is non-inflammable; but, to a limited extent, supports combustion. Hydrogen burns in it readily, but carbon is incapable of direct combination with chlorine. Chlorine does not exist in the free state in nature; it has so great an attraction for hydrogen that it slowly decomposes water, combining with the hydrogen and liberating oxygen in the free state. Water dissolves 2.368 volumes of chlorine at 15° C.; the solution has a powerful bleaching action on vegetable colours, and also is a most efficient disinfectant. Chlorine forms compounds, termed "chlorides," with all other elements.

62. Hydrochloric Acid, HCl.—This, the only known compound of hydrogen and chlorine, is a gaseous body. Hydrochloric acid gas is colourless, fumes on coming in contact with moist air, has a most pungent smell, and is neither inflammable nor a supporter of combustion. One volume of hydrogen unites with one volume of chlorine to produce two volumes of hydrochloric acid gas. The gas dissolves readily in water, one volume of which at 15° C. holds in solution 454 volumes of the gas. The concentrated solution fumes on exposure to air, and smells strongly of the gas; it has an extremely sour taste, and turns litmus solution red. The commercial solution has a specific gravity of about 1.16, and contains about 33 per cent. (one-third) by weight of hydrochloric acid. Hydrochloric acid attacks many of the metals, forming chlorides, with the evolution of hydrogen. Hydrochloric acid and the bases when placed in contact form the salts known as chlorides. Hydrochloric acid and the chlorides may be recognised when in solution by their giving a curdy white precipitate on the additions of dilute nitric acid, and nitrate of silver solution.

63. **Chlorides.**—Common salt, or sodium chloride, $NaCl$, is the most important of the chlorides, and is largely used as an antiseptic or preventative of putrefaction; its effect during fermentation of dough will be discussed hereafter. Other chlorides, as calcium chloride, $CaCl_2$, will be referred to as occasion arises.

64. **Bleaching Powder, or Chloride of Lime, $CaOCl_2$.**—This body is produced by the union of lime (calcium oxide) with chlorine. The addition of almost any acid, even carbon dioxide, is sufficient to effect its decomposition, liberating free chlorine. Chloride of lime is consequently largely used for disinfecting and bleaching purposes.

65. **Carbon, C.**—This element is only known in the solid state, being incapable of liquefaction or vaporisation at the highest temperatures at our command (except possibly at the highest temperatures of the electric arc). It exists in nature, uncombined with other elements, in two forms or varieties most strikingly different from each other. One of these constitutes the gem known as the diamond, the other is graphite, or black lead. Both these bodies are almost pure carbon. Carbon also occurs plentifully as a constituent of animal and vegetable substances, as flesh, bones, fat, wood, leaves, seeds, and the almost numberless bodies that may be obtained from them. Limestone, marble, and chalk rocks contain a large percentage of carbon; so also does coal, which is essentially fossilised wood. From flesh, bones, wood, and many other substances, carbon may be obtained by heating them to redness in a closed vessel: this form of carbon is termed "charcoal," that from bones being "animal," and that from wood "vegetable charcoal." Carbon prepared in this manner, or charcoal, is a black substance. The operation of thus heating a substance in a closed vessel to a temperature sufficiently high to effect its decomposition into volatile liquid and gaseous products, with usually, as in this case, a non-volatile residue, is termed "destructive distillation." All forms of carbon are inflammable. When burned with an insufficient supply of oxygen, carbon monoxide, CO, is produced; with excess of oxygen, carbon dioxide, or CO_2, is formed. Charcoal possesses a most remarkable property of absorbing and condensing gases within its pores; thus, freshly-burnt wood charcoal is capable of absorbing about ninety times its volume of ammonia gas. Charcoal also absorbs considerable quantities of oxygen; and among other gases, those evolved during the putrefaction of animal and vegetable bodies. The gases resulting from putrefaction are largely composed of carbon and hydrogen, and, when thus brought by their absorption within the charcoal so closely in contact with oxygen, are rapidly burned or oxidised to carbon dioxide, water, and more or less of other inodorous and innocuous substances. Charcoal thus acts as a remedy for bad smells, and acts not by masking them by a more powerful odour, but by absorption of the deleterious vapours, and their conversion into harmless products. In this way charcoal is also capable of removing evil smells from water; for instance, water from a stagnant pond on being shaken up with charcoal loses its disagreeable odour. Not only does charcoal act as an absorbent of gases, but it also removes many colouring matters from solution; thus, a syrup of dark brown sugar on being shaken up with animal charcoal, and then filtered, may be made almost colourless. These properties of charcoal have led to its finding much favour as a filtering medium for the purification of water; for this purpose it is, when

fresh, of great efficacy, but after a time loses its activity by being saturated with the bodies it is intended to remove. All filters require from time to time to be taken apart, and the filtering medium removed and replaced by some fresh and pure material. Charcoal may be renovated by being heated to redness in a closed vessel. With these precautions, charcoal forms one of the best filtering agents; but without attention to continuous cleaning, filters, so far from purifying water, become positive sources of the most serious and dangerous impurities. Charcoal is frequently used in the laboratory for decolourising purposes.

66. **Carbon Monoxide, CO.**—This compound is a colourless, odourless and exceedingly poisonous gas. It is formed when carbon dioxide gas passes over or through red-hot charcoal, as it frequently does in a clear coke or charcoal fire. The carbon monoxide thus produced burns with a blue flame on the surface of the fire. Carbon monoxide is also formed, together with free hydrogen, when steam is passed through a red-hot carbon mass, such as a fire of burning coke. The gas is inflammable, and in burning yields carbon dioxide. Carbon monoxide has no action on lime-water.

67. **Carbon Dioxide, CO_2.**—This gas plays a most important part in the chemistry of bread-making. It is colourless, has a sweetish taste, and peculiarly brisk and pungent odour. As carbon dioxide is an essential constituent of aerated waters, its taste and smell are familiar, being those perceived on opening and tasting the contents of a bottle of soda-water. Carbon dioxide is neither inflammable, nor under ordinary circumstances a supporter of combustion. The gas is poisonous to breathe, but may be taken into the stomach without injury. Liquids containing carbon dioxide gas in solution are marked by a pleasant brisk flavour. Carbon dioxide has a density of 22, and is 1.527 times as heavy as ordinary air. In the absence of air currents, it consequently has a tendency to remain a considerable time in a layer on the surface of liquids from which it is being evolved, particularly when they are in somewhat confined spaces. Carbon dioxide is soluble in about its own volume of water; as has already been explained (paragraph 45), when measured by volume the solubility is independent of the pressure to which the gas is subject. Concentrated solutions of carbon dioxide gas in water are prepared by pumping the gas under pressure (some 10 or 12 atmospheres) into a strong vessel, in which it is agitated with water. The solution thus obtained is permanent under pressure, but on its relaxation the carbon dioxide is again liberated in the gaseous state. Carbon dioxide may be obtained in a variety of ways; the simplest is by the burning of carbon, or organic bodies containing carbon in air or oxygen—

$$\underset{\text{Carbon.}}{C} \quad + \quad \underset{\text{Oxygen.}}{O_2} \quad = \quad \underset{\text{Carbon Dioxide.}}{CO_2}.$$

It is also produced when chalk, limestone, or marble (calcium carbonate) is heated to full redness—

$$\underset{\text{Calcium Carbonate.}}{CaCO_3} \quad = \quad \underset{\text{Calcium Oxide (Lime).}}{CaO} \quad + \quad \underset{\text{Carbon Dioxide.}}{CO_2}.$$

Likewise, by gently heating sodium bicarbonate or ammonium carbonate—

$$\underset{\text{Sodium Bicarbonate.}}{2NaHCO_3} \quad = \quad \underset{\text{Sodium Carbonate.}}{Na_2CO_3} \quad + \quad \underset{\text{Water.}}{H_2O} \quad + \quad \underset{\text{Carbon Dioxide.}}{CO_2}.$$

$$\underset{\text{Ammonium Carbonate.}}{(NH_4)_2CO_3} \quad = \quad \underset{\text{Ammonia.}}{2NH_3} \quad + \quad \underset{\text{Water.}}{H_2O} \quad + \quad \underset{\text{Carbon Dioxide.}}{CO_2}.$$

Another method of obtaining carbon dioxide is by treating any carbonate with an acid: the following equations represent a few of the principal of such reactions—

$$\underset{\text{Calcium Carbonate.}}{CaCO_3} + \underset{\text{Hydrochloric Acid.}}{2HCl} = \underset{\text{Calcium Chloride.}}{CaCl_2} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2.}$$

$$\underset{\text{Calcium Carbonate.}}{CaCO_3} + \underset{\text{Sulphuric Acid.}}{H_2SO_4} = \underset{\text{Calcium Sulphate.}}{CaSO_4} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2.}$$

$$\underset{\text{Sodium Carbonate.}}{Na_2CO_3} + \underset{\text{Hydrochloric Acid.}}{2HCl} = \underset{\substack{\text{Sodium Chloride} \\ \text{(Common Salt)}}}{2NaCl} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2.}$$

$$\underset{\text{Sodium Bicarbonate.}}{2NaHCO_3} + \underset{\text{Tartaric Acid.}}{H_2C_4H_4O_6} = \underset{\text{Sodium Tartrate.}}{Na_2C_4H_4O_6} + \underset{\text{Water.}}{2H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2.}$$

Carbon dioxide is also evolved during alcoholic fermentation, and the putrefaction and decay of organic bodies. In addition, carbon dioxide is produced during the respiration of animals, and is an important constituent of the exhaled breath. An aqueous solution of carbon dioxide gas changes the colour of litmus solution from full blue to a port wine tint; such a solution has feebly acid properties and forms with bases the salts termed carbonates. The solution in water may be viewed as carbonic acid, H_2CO_3; hence the gas is frequently called carbonic anhydride. Formerly the term acid was applied, by some chemists, indifferently to the anhydrides and their compounds with water; carbon dioxide then received the name of "carbonic acid gas," by which it is still popularly known. Modern definitions of an acid preclude this name being now correctly applied to what are properly termed anhydrides.

68. Carbonates.—With the exception of those of the alkalies, all carbonates are insoluble in water; many are, however, dissolved by water containing carbon dioxide in solution. The most interesting example of this is the solution of considerable quantities of carbonate of lime in natural waters obtained from the chalk and other limestone deposits. Such waters, although perfectly clear, become turbid on being boiled from fifteen to thirty minutes: the boiling drives off the carbon dioxide, and the calcium carbonate is precipitated in the insoluble state. The formation of carbonates is exemplified by the passage of carbon dioxide gas into lime water, i.e., a solution of lime in water, CaH_2O_2; the insoluble calcium carbonate, or carbonate of lime, is produced, and turns the clear solution milky. This forms a useful and convenient test for the presence of carbon dioxide in any mixture of gases. Most carbonates are easily decomposed by the addition of an acid, with the formation of the corresponding salt of the acid used. Several instances of this action have been given when describing methods for the production of carbon dioxide. The acid- or bi-carbonates have one-half only of the hydrogen replaced by a metal; they may be produced by passing carbon dioxide gas to excess through a solution of the normal carbonates of the alkalies. The bicarbonates are readily decomposed by heat into normal carbonates, free carbon dioxide, and water.

69. Compounds of Carbon with Hydrogen.—These are exceedingly numerous; an account of some of those of most importance will be given when describing the organic bodies more particularly associated with our subject. As a group, they are termed "hydrides of carbon."

70. Nitrogen, N_2.—This gas constitutes about four-fifths, by volume, of the atmosphere; it is also a constituent of ammonia, of nitric acid and its salts, and of many animal and vegetable substances. Nitrogen is colourless, odourless, tasteless, non-inflammable, and a non-supporter of combustion. It does not readily enter into combination with other elements, but may be caused to combine with oxygen by passing a sparking or flaming discharge through a mixture of the two. In the free state nitrogen is marked rather by its neutral qualities than by any positive characteristics. In the uncombined state its principal function is that of a diluting agent in the atmosphere. Although not an active element, nitrogen forms an extensive series of compounds.

71. The Atmosphere.—It has already been stated that the atmosphere consists essentially of oxygen and nitrogen; these gases are not united in any way, but simply form a mechanical mixture. In addition to the nitrogen and oxygen, air contains small quantities of carbon dioxide, water vapour, and traces of other substances. Subjoined is a table showing its average composition:—

	Oxygen, O_2	20.61
	Nitrogen, N_2	77.95
	Carbon Dioxide, CO_2	0.04
	Aqueous Vapour, H_2O	1.40
	Nitric Acid, HNO_3	Traces.
	Ammonia, NH_3	
	Hydrides of Carbon	
In towns	Sulphuretted Hydrogen, SH_2	”
	Sulphur Dioxide, SO_2	

Air, freed from moisture and carbon dioxide, contains the following percentage of nitrogen and oxygen:—

	By Measure.	By Weight.
Nitrogen	79.19	76.99
Oxygen	20.81	23.01
	100.00	100.00

Argon, and the other members of the allied group of elements, are here included with the nitrogen. They altogether amount to about 0.94 per cent. of atmospheric air.

In addition to the bodies already mentioned, air in most localities contains germs of microscopic organisms.

72. Ammonia, NH_3.—Traces of this gas, either in the free state or as salts, are found both in air and in water. Its great natural source is the decomposition of animal and vegetable substances which contain nitrogen as a constituent. In this way, ammonia is continually being formed in nature by the decay of refuse nitrogenous matter, such as the urine and excreta of animals, and other bodies. Many nitrogenous vegetable and animal substances also evolve ammonia on being strongly heated; among these is coal, which thus forms the principal source from which ammonia is now derived. Ammonia is a colourless gas, with a most pungent and characteristic odour: in the concentrated state the gas acts as an irritant poison, but when diluted with air possesses a smell rather pleasant than otherwise. Ammonia does not support combustion, and at ordinary temperatures does not burn in air. The gas is very soluble in water; the solution has the odour of the gas, and constitutes what is commonly known as *liquor ammoniæ;* this must not be confused with the gas condensed by pressure in the absence of water, and which is termed "liquid ammonia." Ammonia acts as a powerful alkali, neutralising the strongest acids, and restoring the blue colour to reddened litmus.

73. Ammonium Salts.—On the addition of an acid, such as either sulphuric or hydrochloric acid, to ammonia, the odour disappears, and the acid, as above stated, is found to be completely neutralised. The reaction may be expressed thus:—

$$\underset{\text{Ammonia.}}{NH_3} + \underset{\text{Hydrochloric Acid.}}{HCl} = \underset{\text{Ammonium Chloride.}}{NH_4Cl.}$$

$$\underset{\text{Ammonia.}}{2NH_3} + \underset{\text{Sulphuric Acid.}}{H_2SO_4} = \underset{\text{Ammonium Sulphate.}}{(NH_4)_2SO_4.}$$

On comparing, in each case, the formula of the resulting compound with that of the acid, it will be seen that the group NH_4 replaces the hydrogen of the acid. This compound, NH_4, cannot exist in the free state, but occurs in a number of chemical compounds, and can be transferred from one to another without undergoing decomposition. It is consequently viewed as a compound radical, and has received the name "Ammonium." The solution of ammonia in water may then be represented as ammonium hydroxide, NH_4HO; this body, which is alkaline to litmus, is then seen to be analogous to sodium hydroxide, NaHO, the ammonium occupying a corresponding place to the sodium. This is seen the more clearly when a comparison is instituted between the action of the same acid upon each:—

$$\underset{\text{Ammonium Hydroxide.}}{NH_4HO} + \underset{\text{Hydrochloric Acid.}}{HCl} = \underset{\text{Ammonium Chloride.}}{NH_4Cl} + \underset{\text{Water.}}{H_2O.}$$

$$\underset{\text{Sodium Hydroxide.}}{NaHO} + \underset{\text{Hydrochloric Acid.}}{HCl} = \underset{\text{Sodium Chloride.}}{NaCl} + \underset{\text{Water.}}{H_2O.}$$

Ammonium is often represented by the symbol "Am." instead of NH_4. The stronger bases, as lime, CaO, or soda, NaHO, decompose ammonium salts with the liberation of ammonia:—

$$\underset{\text{Ammonium Chloride.}}{NH_4Cl} + \underset{\text{Sodium Hydroxide.}}{NaHO} = \underset{\text{Sodium Chloride.}}{NaCl} + \underset{\text{Ammonia.}}{NH_3} + \underset{\text{Water.}}{H_2O.}$$

All ammonium salts volatise on being heated, leaving no residue, unless the acid be non-volatile, in which case the acid remains behind.

74. Oxides and Acids of Nitrogen.—No less than five distinct compounds of nitrogen with oxygen are known. The following is a list of their names and formulæ—

Nitrous Oxide	N_2O
Nitric Oxide	NO (or N_2O_2)
Nitrogen Trioxide, Nitrous Anhydride	N_2O_3
Nitrogen Peroxide	NO_2 or N_2O_4
Nitrogen Pentoxide, Nitric Anhydride	N_2O_5

Two of these oxides, the trioxide and pentoxide, form acids with water—the acids being nitric acid, HNO_3, and nitrous acid, HNO_2.

The first and last of this series of oxides have little or no connection with our present subject, but the intermediate three are of much interest and importance as being the agents of a successful flour bleaching process. For this reason a brief description of their properties is necessary.

75. Nitric Oxide, NO.—Formerly, N_2O_2 was considered possibly to represent the constitution of the molecule of this body, but from its density, the molecule must be regarded as consisting of NO. The N_2O_2 formula is given above in brackets, in order to show the relationship in composition between this and the other oxides of nitrogen. When nitric acid is added to metallic copper, an abundance of ruddy fumes is evolved; but if the operation be conducted in a flask fitted in the ordinary way with a thistle funnel and leading tube, the coloured fumes are seen to be swept out of the flask, which soon becomes filled with a colourless gas, which may be collected over water in the pneumatic trough. This colourless gas is nitric oxide. If a gas jar be partly filled with nitric oxide and then oxygen admitted bubble by bubble, a red colour is seen to develop with each introduction. This rapidly disappears, and simultaneously the water rises in the jar. By careful addition of oxygen the whole of the gas (assuming its purity) may be thus rendered soluble. Nitric oxide is only very slightly soluble in water, and possesses the property of immediately combining with free oxygen to produce nitrogen peroxide, NO_2. Nitrogen peroxide is a ruddy coloured gas, and is very soluble in water. A convenient method of preparing nitric oxide consists of allowing nitric acid to drop into a solution of ferrous sulphate, and at the same time passing a current of air through the solution. The air comes over, carrying with it the gas; the proportion of the latter may be regulated by adjusting the rate at which the nitric acid is allowed to drop into the solution. The following is the nature of the chemical change:—

$$\underset{\text{Nitric Acid.}}{8HNO_3} + \underset{\text{Ferrous Sulphate.}}{6FeSO_4} = \underset{\text{Ferric Sulphate.}}{2Fe_2(SO_4)_3} + \underset{\text{Ferric Nitrate.}}{Fe_2(NO_3)_6} + \underset{\text{Nitric Oxide.}}{2NO} + \underset{\text{Water.}}{4H_2O.}$$

In the presence of air, the nitric oxide is immediately converted into the peroxide.

76. Nitrogen Peroxide, NO_3.—At a temperature of 26.7° C., this gas has a density which indicates that about 80 per cent. of its molecules consist of N_2O_4, the remaining ones being composed of NO_2. As the temperature of the gas is raised, the density diminishes, and at 140.0° is 23.00, which corresponds to the whole of the gas being dissociated with NO_2 molecules. Nitrogen peroxide is absorbed and decomposed by water; in the presence of very small quantities of the latter nitrous and nitric acids are thus formed:—

$$\underset{\text{Nitrogen Peroxide.}}{N_2O_4} + \underset{\text{Water.}}{H_2O} = \underset{\text{Nitric Acid.}}{HNO_3} + \underset{\text{Nitrous Acid.}}{HNO_2.}$$

At ordinary temperatures, and with water in excess, nitric acid and nitric oxide are produced thus:—

$$\underset{\text{Nitrogen Peroxide.}}{3NO_2} + \underset{\text{Water.}}{H_2O} = \underset{\text{Nitric Acid.}}{2HNO_3} + \underset{\text{Nitric Oxide.}}{NO.}$$

From the ease with which nitrogen peroxide loses an atom of oxygen and becomes nitric oxide, it is a powerful oxidising agent. Its efficiency as such is greatly increased by the property possessed by nitric oxide of at once combining with free oxygen and again producing nitrogen peroxide. In this way a very small quantity of nitrogen peroxide, by its successive reductions and oxidations, may act as a carrier of oxygen to a relatively large quantity of oxidisable material.

77. Nitrogen Trioxide, N_2O_3.—Nitrogen trioxide is a very unstable compound which can only exist at low temperatures, and readily decomposes into a mixture of nitric oxide and nitrogen peroxide. With water it forms nitrous acid, HNO_2, and this in turn yields salts known as nitrites. These bodies are fairly stable, and potassium nitrite, KNO_2, is an example. Nitrites are found in many drinking waters as an intermediate product in the oxidation to nitrates of nitrogenous matter that may have been present.

78. Nitric Acid, HNO_3.—This is by far the most important oxy-compound of nitrogen. Its usual source in nature is the oxidation of animal matter in the soil. The nitric acid thus produced is found in combination with some base, usually as potassium or calcium nitrate. Pure nitric acid is a colourless fuming liquid; commonly, however, the acid is of a slightly yellow tint, from the presence of some of the lower oxides of nitrogen. The pure acid has a specific gravity of 1.52, and mixes with water in all proportions. Nitric acid is a most powerful oxidising agent, and attacks most animal and vegetable tissues with great vigour. It also freely dissolves most of the metals, forming nitrates. Gold and platinum are not affected by this acid when pure, but are dissolved with the formation of chlorides by a mixture of nitric with hydrochloric acid. Reducing agents convert nitric acid into nitrous acid, or some one or more of the oxides of nitrogen containing less oxygen. Under favourable circumstances, nitric acid may even be reduced to ammonia; that is, the whole of its oxygen may be removed, and its place occupied by hydrogen.

79 **Nitrates.**—The principal of these is potassium nitrate, KNO_3. Like nitric acid, the nitrates are powerful oxidising agents.

80. **Sulphur, S_2.**—This element, in its common form, is a brittle yellow solid, which burns in air or oxygen with the formation of sulphur dioxide, SO_2. The principal interest of sulphur, in connection with our present subject, lies in its compounds. In addition to its occurrence in many inorganic bodies, sulphur is one of the constituents of albumin and other animal and vegetable substances.

81. **Sulphuretted Hydrogen, SH_2.**—This body is a colourless gas, having a most disgusting odour, resembling that of rotten eggs; the gas is soluble in water, which at 15° C. dissolves 3.23 volumes of sulphuretted hydrogen. During the decomposition of substances, either of animal or vegetable origin, containing sulphur, sulphuretted hydrogen is one of the bodies evolved; it is from the presence of this gas that rotten eggs acquire their characteristic odour. Sulphuretted hydrogen is inflammable, and produces water and sulphur dioxide by its combustion. Moist sulphuretted hydrogen undergoes, in the presence of oxygen, slow oxidation, with the formation of water and deposition of free sulphur:—

$$\underset{\text{Sulphuretted Hydrogen.}}{2H_2S} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Sulphur.}}{S_2} + \underset{\text{Water.}}{2H_2O.}$$

82. **Sulphur Dioxide, SO_2.**—This gas is produced by the combustion of sulphur in either air or oxygen: it is colourless, has a pungent odour, recognised as that of burning sulphur; is neither inflammable nor a supporter of combustion. Sulphur dioxide is soluble in water, which at a temperature of 15° C. dissolves 47 volumes of the gas; the solution thus formed tastes and smells of the gas, it reddens and finally bleaches a solution of litmus. Sulphur dioxide is one of the most powerful antiseptics known. The gas is easily condensed to the liquid state by either cold or pressure. Liquid sulphur dioxide is supplied commercially in syphons, similar to those used for soda water.

83. **Sulphurous Acid, H_2SO_3, and the Sulphites.**—Sulphur dioxide when dissolved in water produces a somewhat unstable acid, H_2SO_3. The sulphites, or salts of this acid, are mostly insoluble in water, the principal exceptions being sodium sulphite, Na_2SO_3, and potassium sulphite. In addition to the normal sulphites, acid or bisulphites occur; these may be produced by passing excess of sulphur dioxide into a solution of the normal salts. The bisulphites readily evolve sulphur dioxide on being heated. Calcium sulphite is insoluble in water, but dissolves in a solution of sulphurous acid, forming calcium bisulphite, or, as commonly called, "bisulphite of lime." Bisulphite of lime is largely used as an antiseptic. Under the influence of oxidising agents, sulphurous acid and the sulphites are oxidised to sulphuric acid and sulphates.

84. Sulphuric Acid, H_2SO_4, and the Sulphates.—Sulphuric acid is one of the most useful chemical compounds known, forming as it does the starting point in the manufacture of a number of substances of vast importance in the arts. When in the pure state, sulphuric acid is a colourless, odourless liquid of an oily consistency: this latter property has led to its receiving the popular name of "oil of vitriol"; the acid, however, is in no way connected chemically with the class of bodies known as fats or oils. Sulphuric acid is nearly twice as heavy as water, having a specific gravity of 1.842; it boils at a temperature of 338° C. Sulphuric acid has a great attraction for water, with which it combines to form definite hydroxides (*i.e.* chemical compounds with water); considerable heat is evolved during the act of union. In consequence of this affinity for water, sulphuric acid is largely used as a desiccating or drying agent; on exposure to the air the acid rapidly increases in weight by absorption of water vapour, and the air becomes dry; hence, if a vessel of sulphuric acid be placed under a bell jar, it speedily produces a dry atmosphere inside. Less concentrated varieties of the acid form staple articles of commerce. Owing to this attraction for water, sulphuric acid is a most corrosive body; wood, paper, and most vegetable and animal substances are vigorously attacked by it; the acid combines with the hydrogen and oxygen of the substance in the proportions in which they form water, and leaves behind a mass of carbon, together with any excess of either hydrogen or oxygen that may have been present. This, of course, does not in all cases represent the whole of the chemical action that may have occurred. Dilute sulphuric acid contains water in excess, and therefore does not exhibit this dehydrating tendency when placed in contact with other bodies; it is well to remember this, because in a number of reactions, where dilute sulphuric acid is employed, it produces not merely less energetic action, but action absolutely opposite in character to that of the concentrated acid. The dilute acid, if allowed to evaporate in contact with paper, etc., acts in a similar manner to the strong acid, as the water dries off. Sulphuric acid forms a normal and an acid series of salts, of which Na_2SO_4, sodium sulphate, and $NaHSO_4$, acid sodium sulphate, are, respectively, examples. Most of the sulphates are more or less soluble in water; calcium sulphate is only slightly so; barium sulphate is insoluble in water and dilute acids. Sulphuric acid and the sulphates may be detected in solution by the addition of hydrochloric acid and barium chloride, when they produce a white precipitate of $BaSO_4$.

85. Bromine, Br_2; Iodine, I_2; and Fluorine, F_2.—These three elements are very closely allied in properties to chlorine; they have no very intimate connection with the chemistry of wheat and flour. Bromine is a liquid; iodine, at ordinary temperatures, is a solid body. Iodine is slightly soluble in water, readily soluble in alcohol or a solution of potassium iodide, KI. Iodine, or its solution, produces a characteristic blue colour with starch: this reaction is of great delicacy, and is an exceedingly valuable test both for starch and iodine. Fluorine forms an acid with hydrogen, hydrofluoric acid, HF, which is characterised by its power of attacking and dissolving glass and the silicates generally.

86. Silicon, Si; Silica, SiO_2; and the Silicates.—Silicon is an element somewhat resembling carbon in some of its properties; all that at present need be stated about it is that it forms with oxygen an oxide, SiO_2, analogous in composition to that of carbon, CO_2. This oxide, SiO_2, is termed silica, or at times, silicic anhydride. Flint and quartz are almost chemically pure forms of silica; in this form silica is insoluble in water and all acids, and mixtures of acids, except hydrofluoric acid. On being fused with an alkali as KHO, or an alkaline carbonate, K_2CO_3, silica produces a glassy substance entirely soluble in water: this body is potassium silicate, K_4SiO_4, and from it, silicic acid, H_4SiO_4, may be obtained. Silicic acid is soluble in water and is tasteless and odourless; on being gently evaporated it first forms a jelly, and then, as the whole of the water is driven off, the silica remains as a white powder, once more insoluble in water and acids. As silica produces a compound with water which, by action on bases, forms salts, silica is rightly viewed as an anhydride. The silicates are the principal constituents of the great rock masses of the earth and of soil. The natural silicates usually contain two or more of the following bases—iron oxides, alumina, lime, magnesia, potash, and soda. With the exception of those of potash and soda, the silicates are mostly insoluble.

87. Phosphorus, P_4; Phosphoric Acid, H_3PO_4; and the Phosphates.—Like several other elements, phosphorus assumes more than one distinct form. The commoner variety is a crystalline body, often called yellow phosphorus. In addition there is an amorphous variety, which from its colour is frequently known as red phosphorus. In properties, the ordinary or yellow phosphorus is one of the most striking of the elements; its attraction for oxygen is so great that it has to be kept under water in order to prevent its oxidation. In process of manufacture, the ordinary phosphorus is usually cast into sticks of a light yellow colour and the consistency of wax; a piece of phosphorus appears luminous in the dark when exposed to air; this is caused by its slow combustion. A slight elevation of temperature, or even friction, suffices to cause phosphorus to burn vigorously; it then produces a vivid light, and forms, by union with oxygen, phosphorus pentoxide, P_2O_5, or, as it is sometimes termed, phosphoric anhydride. Phosphoric anhydride, as thus formed, is a white powder, which combines with water with great avidity to form phosphoric acid, H_3PO_4. Phosphoric acid is principally of interest because of its salts, known as phosphates: of these the most important to us are calcium phosphate, $Ca_3(PO_4)_2$; and potassium phosphate, K_3PO_4. Calcium phosphate is the principal constituent of the mineral matter of bones, and hence in some form or other is an absolutely essential article of food. Phosphates occur in some parts of all plants, and is derived by them from the soil. In wheat, the phosphoric acid is mostly combined with potassium. The alkaline phosphates are soluble in water; the others are insoluble, but may be readily dissolved by the addition of nitric or hydro chloric acid.

88. The Metals and their Compounds.—Within the limits of this work it would be impossible to give even the briefest systematic description of these bodies. An account follows of calcium and potassium, but such other metallic compounds as have any bearing on our subject will be described when reference to them is made.

89. Calcium, Ca, and its Compounds.—Until comparatively recently, calcium was scarcely more than known in the free state. It is a silver-white metal, and has such an attraction for oxygen that it very readily becomes oxidised on exposure to moist air, with the formation of calcium oxide There are two oxides of calcium, but only the monoxide is of practical importance in connection with the present subject. This body, CaO, is that commonly spoken of as "quicklime." The salts of calcium are sometimes referred to as salts of lime; this is not strictly correct, but in most cases makes no real difference. To this there is one exception. Chloride of calcium, or calcium chloride, is $CaCl_2$; chloride of lime is a very different body, $CaOCl_2$. Calcium oxide is a whitish-grey substance, usually obtained by the action of heat on the carbonate; it is infusible at the highest temperatures. Calcium oxide combines readily with water, with the evolution of considerable heat, forming slaked lime, or calcium hydroxide, CaH_2O_2. Calcium hydroxide occurs as a dry, white powder, which is soluble in water to the extent of one part in 600. This solution is that known as "lime-water," and is employed as a test for carbon dioxide. The solution of lime has a decidedly alkaline reaction, turning reddened litmus blue. Calcium produces an extensive series of salts; of these calcium carbonate has been already referred to when describing carbon dioxide. The next most important salt is calcium sulphate; this body is only slightly soluble, one part being dissolved by about 400 parts of water. The phosphate and chloride have already been referred to; the latter has a great affinity for water, and consequently is often used as a drying agent; it can be frequently used where sulphuric acid would be unsuitable from its other properties.

90. Potassium, K, and its Compounds.—Potassium is a soft bluish white metal, which has so great an attraction for oxygen that it has to be kept from contact with the air, and even liquids as water, which contain oxygen as one of their compounds; for this purpose the potassium is generally preserved in mineral naphtha, a compound of carbon and hydrogen. The normal oxide of potassium is K_2O; this body has such affinity for water that it practically never occurs in the anhydrous state, but usually as the hydroxide, KHO. Potassium hydroxide is a white crystalline solid substance; it melts at a red heat, and is supplied commercially either in sticks, or in lumps produced by breaking up fused slabs of the compound. Potassium hydroxide is a powerfully caustic body, and rapidly destroys animal tissues. It is one of the most powerful alkalies known, restoring the blue colour to reddened litmus, and forming salts with acids. Potassium hydroxide decomposes ammonium salts with the liberation of ammonia; sodium hydroxide and lime behave similarly in this respect. Potassium hydroxide is very soluble in water; the solution has a peculiar soapy feel to the fingers. Potassium hydroxide has a great attraction for carbon dioxide; its solution absorbs that gas with great rapidity, forming potassium carbonate, K_2CO_3. Potassium carbonate is a white deliquescent body; i.e. one that readily becomes moist through the absorption of water. Like other deliquescent bodies, potassium carbonate is very soluble in water; the solution is strongly alkaline to litmus, although the salt is of normal constitution. As already explained, the very strong bases produce with certain weak acids normal salts, in which the alkaline compound may be said to predominate. Potassium carbonate was at one time almost exclusively obtained from wood ashes. An acid potassium carbonate, $KHCO_3$, is also known; this body is neutral to litmus, and is less soluble in water; it is at a temperature of 80° C. decomposed into the normal carbonate and free acid.

91. Sodium Compounds.—Sodium forms a series of compounds which closely resemble those of potassium; of these the most familiar are sodium hydroxide, NaHO; sodium carbonate, Na_2CO_3; acid sodium carbonate, $NaHCO_3$; and sodium chloride, NaCl. Sodium hydroxide is a somewhat less powerful base than potassium hydroxide.

CHAPTER III.

DESCRIPTION OF ORGANIC COMPOUNDS.

92. "Organic" Chemical Compounds.—Chemical science is commonly divided into two branches, known respectively as "Inorganic" and "Organic" chemistry. Certain substances, whether they occur in nature, or are prepared in the laboratory, are obtained from mineral sources: the bodies described in the preceding chapter are instances of such compounds. There are, on the other hand, bodies which are obtained either from the animal or vegetable kingdom. Animals and vegetables are organised bodies, that is, they have definite organs which adapt them for that series of processes which constitutes what is called "life"; hence chemical compounds having a vegetable or animal origin are termed "organic." Those which are not thus obtained from organic sources are termed "inorganic" compounds: the two names have also been given to the branches of chemistry which treat respectively of these two classes of bodies, and of their properties and reactions. It was formerly supposed that the so-called organic bodies could only be obtained from organic sources; but chemical investigation has demonstrated that many such compounds can be produced by artificial means from the elements of which they are composed, without the intervention of living organisms, and even under such conditions as render the existence of living organisms an impossibility. Alcohol and its derivatives are examples. The definition of an organic body as one produced as a result of "life" is evidently no longer tenable, and chemists have endeavoured, with more or less success, to frame new definitions of organic chemistry. As **all organic compounds contain carbon,** it has been proposed to define it as the "chemistry of the carbon compounds"; again, as many organic bodies are well defined compound radicals, the phrase "chemistry of the compound radicals" has been proposed. These definitions have not been found entirely satisfactory, as they are either too wide or too narrow. They present the further difficulty that they are not modifications or explanations of the term organic chemistry, but are totally new phrases. As this branch of chemistry is still called organic chemistry, and the compounds included in its scope are still called organic compounds, the student of the chemistry of bread-making may regard **Organic Chemistry as that branch of the science which treats of the composition and properties of those compounds whose usual or original source is or was either animal or vegetable.** This explanation of the meaning of organic chemistry has the defect that it does not include all those substances now known as organic compounds; but all such compounds thus excluded are without any direct bearing on the chemistry of wheat, flour, or bread.

93. Organised Structures.—Although organic compounds can be prepared by artificial means, it must be clearly understood that **no chemical processes have as yet been found capable of producing an organised structure**; further, all evidence hitherto obtained, so far as it goes, tends to prove the impossibility of such structures being formed other than through living agencies. For instance, starch is found, when viewed under the microscope, to have a structural organisation peculiar to itself. Starch may be dissolved, and after such solution again obtained in the solid state; but the solid thus produced shows no trace of the original structure of the grains of starch; neither is there known any artificial process by which the starch may again be built up into structures of the same kind as those in which it originally occurred. Similarly, it is impossible to artificially produce a blood corpuscle. The same law applies to minute organisms, as yeast, *bacteria,* etc.; none of these can be generated otherwise than through the agency of previously existing living beings of the same type. So far as any problem can be proved scientifically, **this fact of the impossibility of spontaneous generation is abundantly demonstrated**; experimental evidence of a most conclusive character has shown as certainly as scientific research can, in any case, possibly show, that living organisms can only be formed by means of similar pre-existing organisms.

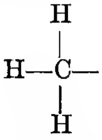
94. Composition of Organic Bodies.—Organic compounds, generally, have a much more complicated chemical composition than have inorganic compounds; they are mostly; however, restricted to comparatively few elements. All organic bodies contain carbon; many are composed of carbon and hydrogen only, a greater number consist of carbon, hydrogen, and oxygen; while others contain the four elements, carbon, hydrogen, oxygen, and nitrogen. The majority of organic compounds belong to one or other of these series. Carbon, more than any other element, is remarkable for the property of, in compounds, combining directly with itself, and so forming most complicated bodies out of comparatively few elements.

95. Classification of Organic Compounds.—The number of these is so bewildering that, without some classification, it would be impossible to grasp their relationship to each other: recent chemical science has succeeded in very clearly demonstrating the constitution of a vast number of these bodies. There are, in the first place, large numbers of well defined compound radicals, consisting of carbon and hydrogen: it has been found possible to group these into distinct families, the members of each of which may be represented by a common formula.

96. Organic Radicals.—The most important series of these is that known as the "Methyl," or "Ethyl" series; these have the common formula $(C_nH_{2n+1})_2$. This formula signifies that in the first place the molecule consists of two semi-molecules that are similar in composition; secondly, that in each semi-molecule the number of atoms of hydrogen is one more than double the number of atoms of carbon. The following is a list of a few of the radicals of this series:—

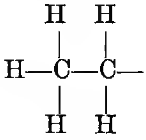
Methyl ..	Me_2 ..	$\left\{\begin{matrix}CH_3\\CH_3\end{matrix}\right.$
Ethyl ..	Et_2 ..	$\left\{\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right.$, or $\begin{bmatrix}CH_3\\CH_2\end{bmatrix}_2$, or $\left\{\begin{matrix}CMeH_2\\CMeH_2\end{matrix}\right.$
Propyl ..	Pr_2 ..	$\left\{\begin{matrix}C_3H_7\\C_3H_7\end{matrix}\right.$, or $\left\{\begin{matrix}CEtH_2\\CEtH_2\end{matrix}\right.$
Butyl ..	Bu_2 ..	$\left\{\begin{matrix}C_4H_9\\C_4H_9\end{matrix}\right.$
Amyl ..	Ay_2 ..	$\left\{\begin{matrix}C_5H_{11}\\C_5H_{11}\end{matrix}\right.$
Caproyl ..	Cp_2 ..	$\left\{\begin{matrix}C_6H_{13}\\C_6H_{13}\end{matrix}\right.$

Each semi-molecule of these radicals behaves in compounds as though it were an atom of a monad element; the atomicity is shown by the following graphic formulæ—



$$\begin{array}{ccc} & H & \\ & | & \\ H- & C & - \\ & | & \\ & H & \end{array}$$

Methyl.



$$\begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H- & C & - & C & - \\ & | & & | & \\ & H & & H & \end{array}$$

Ethyl.

From these formulæ it is seen that in each case there is one of the carbon bonds free; in the free state two semi-molecules unite by these bonds to form the molecule. The graphic formulæ also show how each of the higher radicals of the series may be viewed as compounds of the next lower radical with an additional CH_2. The temperature of the boiling points of these bodies increases as the series is ascended.

97. Hydrides of Organic Radicals (Paraffin Group).—These bodies are compounds of the radicals with hydrogen; those of the series already referred to have the general formula C_nH_{2n+2}. Among them there is, as the lowest, methane or methyl hydride (marsh gas), CH_3H or CH_4; from this the series ascends regularly to $C_{16}H_{34}$. These compounds are distinguished by their not being readily attacked by the most powerful oxidising agents, they consequently have received the name of "paraffins" (from the Latin, *parum affinis,* having little affinity). The lower members of the series are gases, the middle are liquids, and the higher members are solid at ordinary temperatures. The paraffins are produced by the destructive distillation of wood, coal, and many other organic substances, and also occur in rock-oils. Some varieties of American petroleum consist almost entirely of paraffins. In distilling the crude petroleum, it is found that the temperature of the vapour produced rises as the operation progresses. The more volatile portions distil off first; the distillate may be collected in separate portions or fractions; the operation is then termed "fractional distillation." The lighter or more volatile paraffins constitute what is known as light petroleum spirit; this substance, when carefully freed from solid impurities, is of great use as a solvent for fatty substances, both in the arts and chemical analysis. Good light petroleum spirit should distil entirely at a temperature of 70° C. Such spirit is a mixture of several of the lower paraffins. The petroleum of commerce consists of a somewhat higher fraction, and mineral lubricating greases and "vaseline" of a yet less volatile portion. The least volatile portion of all constitutes, when pure, the hard white solid substance known as "solid paraffin," or paraffin "wax."

98. The Alcohols.—In constitution, these bodies bear the same relation to the organic radicals as do the metallic hydroxides to the metals. This is clearly seen on writing representative formulæ of the two side by side:—

C_2H_5HO	$NaHO$
Ethyl, or ordinary, Alcohol.	Sodium Hydroxide.

Certain chemists carry this analogy so far as to regard the alcohols as hydrates (hydroxides) of the radicals, and term ordinary alcohol, "ethylic hydrate." To this the objection has been taken that the alcohols do not contain water, and that the hydroxides are really hydrated oxides, or oxides formed by the union of water with the normal oxide, as, for example:—

$$Na_2O + H_2O = 2NaHO.$$

The argument is, however, addressed to the composition of these bodies rather than to the mode of formation; and it is clear that these bodies may be regarded as compounds of the organic radicals with hydroxyl (HO). It is then simply a matter of definition whether or not the term hydrate or hydroxide shall be understood to mean a compound with hydroxyl. The alcohols are sometimes conveniently regarded as substitution products of the paraffins; thus ethyl alcohol may be viewed as ethane, C_2H_6, in which hydroxyl is substituted for one of the atoms of hydrogen. In this manner the relationship between the alcohols and the paraffins is clearly seen. Like metallic hydroxides, the alcohols enter into combination with acids to form organic salts. Thus ethyl alcohol, being C_2H_5HO, is converted by the action of hydrochloric acid into C_2H_5Cl, ethyl chloride. This reaction is analogous to that by which sodium hydroxide is converted into sodium chloride, as is shown by the respective equations:—

$$\underset{\text{Alcohol or Ethyl Hydroxide.}}{C_2H_5HO} + \underset{\text{Hydrochloric Acid.}}{HCl} = \underset{\text{Ethyl Chloride.}}{C_2H_5Cl} + \underset{\text{Water.}}{H_2O.}$$

$$\underset{\text{Sodium Hydroxide.}}{NaHO} + \underset{\text{Hydrochloric Acid.}}{HCl} = \underset{\text{Sodium Chloride.}}{NaCl} + \underset{\text{Water.}}{H_2O.}$$

Of the various alcohols, those of the methyl series are the most important, and are represented by the formula, $C_nH_{2n+1}HO$. Subjoined are a few examples of these compounds:—

Methyl Alcohol, CH_3HO, or $\left\{\begin{matrix} H \\ CH_2HO. \end{matrix}\right.$ Butyl Alcohol, C_4H_9HO.
Ethyl „ C_2H_5HO, or $\left\{\begin{matrix} CH_3 \\ CH_2HO. \end{matrix}\right.$ Amyl „ $C_5H_{11}HO$.
Propyl „ C_3H_7HO. Melissic „ $C_{30}H_{61}HO$.

The lower members of the series are liquid, and the higher solid.

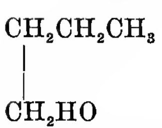
99. Methyl Alcohol, CH_3HO.—This body, in an impure form, is yielded on the destructive distillation of wood, and hence is commonly known as "wood spirit," or "wood naphtha." This crude preparation has a nauseous flavour, which renders it unfit for drinking: the pure methyl alcohol has, on the contrary, a purely spirituous taste and odour. Methyl alcohol mixes in all proportions with water, ethyl alcohol, and ether; it has at 15° C. a specific gravity of 0.8021.

100. Ethyl Alcohol, $\left\{\begin{matrix} CH_3 \\ CH_2HO, \end{matrix}\right.$ or C_2H_5HO.—This body constitutes the active ingredient of beer, wine, and of all spirituous liquors, as brandy, whisky, etc. The term "alcohol," when used without any prefix, is always understood to refer to this compound, which is known popularly as "spirits of wine." Alcohol may be produced artificially from its elements by purely chemical means, but is always manufactured by the process of fermentation, of which a detailed account is hereafter given. Pure ethyl alcohol is a colourless, mobile liquid, having an agreeable spirituous odour, and a burning taste. Alcohol is inflammable, and burns with a scarcely luminous smokeless flame, evolving considerable heat; it is on this account largely used in "spirit" lamps as a fuel. Alcohol rapidly evaporates at ordinary temperatures, and when pure, boils at 78.4° C. (=173.1°) F. At a temperature of 15.5° C., alcohol has a specific gravity of 0.79350; that of water, at the same temperature, being taken as unity. Alcohol mixes with water, and also ether, in all proportions: for the former compound it has a great affinity, and evolves considerable heat on the two being mixed; the volume of the mixture is less than that of the two liquids taken separately. As previously mentioned, alcohol is manufactured by fermentation; this process is only capable of producing a comparatively dilute solution of alcohol in water. In order to obtain a stronger spirit, the fermented liquid is distilled; as alcohol boils at a lower temperature than water, the earlier portions of the distillate are the stronger in spirit, until finally no alcohol remains in the liquid being distilled. It is not possible to obtain in this manner alcohol free from water, as even the very first portions of spirit which distil over carry water with them. By several times distilling the spirit it is possible to obtain a mixture containing about 90 per cent. of the pure spirit; special distilling arrangements have resulted in the production of a distillate containing as much as 95 per cent. of alcohol. In order to remove this small quantity of water, the spirit is treated with quicklime or potassium carbonate, and then allowed to stand, and after a time distilled: in this manner alcohol can be obtained in which there is only the most minute trace of water. This desiccated alcohol is termed "absolute" alcohol. Alcohol is of very great use as a solvent, particularly for many organic bodies; it also acts as an antiseptic, and hence is employed for the preservation of biological and other specimens. The solvent power of alcohol is modified considerably by its admixture with more or less water: for many purposes alcohol of a certain definite strength is necessary. As water and alcohol have different densities, and as density is easily measured, it is a usual method of testing the strength of alcohol to take its specific gravity. Tables have been prepared giving the strength in percentages of alcohol present for different densities. Three distinct standards of strength of alcoholic spirit are commercially recognised. The "rectified spirit of wine" of the British Pharmacopœia is the strongest spirit that can be produced by the ordinary methods of distillation: such spirit should contain 84 per cent. by weight of absolute alcohol, and should have a density of 0.838. "Proof spirit" is a term that has survived its original application: it is now legally defined as spirit of such a strength that 13 volumes of it shall weigh at 51° F. the same as 12 volumes of water at the same temperature. Proof spirit has at 15.5° C. a density of 0.91984, and contains 49.24 per cent. by weight of alcohol and 50.76 of water. Weaker spirits are defined as being so many degrees "under proof" (U.P.), while stronger spirits are referred to as being so many degrees "over proof" (O.P.). A spirit of 10 degrees U.P. is such that it contains 90 per cent. of proof spirit and 10 per cent. of water; spirit of 10 degrees O.P. is of such a strength that it may be made up to 110 volumes by the addition of water, and would then have the same percentage of alcohol as proof spirit. Absolute alcohol is that, as before stated, which contains no water. For chemical purposes it is usual to specify the strength of alcohol, either as so much per cent. spirit, or by its density. When for any purpose it is directed that alcohol of a certain strength must be employed, particulars will be given as to its density; for complete tables of densities and corresponding strengths, the larger treatises on chemistry must be consulted.

101. Detection of Alcohol.—Alcohol when present in any quantity is easily recognised by its smell; in liquids which contain traces only, it is best to distil and then examine the first portions of the distillate. When using a Liebig's condenser, it will be seen, at the point where the vapour begins to condense, that when alcohol is present, the distillate trickles down the sides of the tube in peculiar oily looking drops or "tears." This appearance ceases as soon as the whole of the alcohol has distilled off. Very minute quantities of alcohol suffice to produce this effect. Another and more delicate method for its detection depends on the production of iodoform. This body has the symbol CHI_3, and is similar in constitution to chloroform, $CHCl_3$. The liquid under examination should first be distilled, and the tests applied to the first portion of the distillate. Ten c.c. are to be taken and rendered alkaline by the addition of about a quarter of a c.c. (five or six drops) of a 10 per cent. solution of sodium hydroxide; the liquid must next be warmed to about 50° C., and then a solution of potassium iodide, saturated with iodine, added drop by drop until a slight excess of free iodine is present; this is indicated by the liquid acquiring a permanent sherry yellow tint. The liquid must next be just decolourised by the addition of a minute quantity of the sodium hydroxide solution. If there be any alcohol present, a yellow crystalline precipitate of iodoform gradually forms. Certain other organic compounds, however, are capable of producing the same reaction.

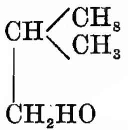
102. Methylated Spirits of Wine.—Alcoholic liquors are subject to a high duty; consequently, for purposes other than the production of drinkable spirits, the Excise authorities permit the sale, duty free, of a mixture of rectified spirit with some substance which imparts a flavour sufficiently nauseous to render the whole absolutely undrinkable, except to the palates of the most debased dipsomaniacs. Formerly spirit was thus "denatured" by the addition of one volume of commercial wood spirit to nine volumes of rectified spirit. Being produced by the addition of crude methyl alcohol, the mixture was known as "methylated spirits of wine." Other bodies are now used for "methylating," among them being some of the lighter paraffins. For most laboratory operations, methylated spirits can be used as a substitute for rectified spirits of wine: for delicate purposes it is well to re-distil the spirits prior to use. On diluting the distilled spirit to about 70 per cent. strength, opalescence is produced. This is due to paraffin which distils over, and is insoluble in the mixture of spirit and water. As the cloudiness is due to the presence of a volatile substance, it does not interfere with many, or even most, uses to which the spirit is applied. Methylated spirits may be rendered almost absolute by adding about one-third of its weight of recently burned quicklime, and thoroughly shaking; the mixture must be allowed to stand some three or four days, and the shaking repeated two or three times daily. The spirit must then be distilled, precautions being taken to prevent the temperature unduly rising. The still should be fixed in a water bath, consisting of an iron saucepan containing brine. The clear portions of the spirits should first be poured into the still, without disturbing the sediment, and distilled to dryness by application of heat to the water bath. Care must be taken that the bath does not boil dry. The pasty mass of lime may next be placed in the still, preferably in small quantities at a time, and heated by the bath so long as any alcohol distils over. An efficient condensing worm must be used, and the tube connecting it with the still ought to be a long one. At the close of the operation the lime may be removed from the vessel used as a still by soaking with water.

103. Propyl, Butyl, and Amyl Alcohols.—These bodies are produced in small quantities during fermentation. They all boil at a higher temperature than ethyl alcohol, and are found in the residual liquor after most of the spirit has been distilled over. Propyl alcohol occurs in the residues of the distillation of the fermented liquor of the marc of grapes in the production of low-class brandy. Normal butyl alcohol occurs in genuine cognac, from which it may be obtained by fractional distillation: it has a boiling point of 116.8° C., and possesses an agreeable odour. But spirits from potatoes, beet-root, maize, and certain other substances contain isobutyl alcohol, an isomeride of the normal alcohol. Isobutyl alcohol has a disagreeable fusel-oil-like odour. The following formulæ indicate their difference in constitution:—



$$\begin{matrix}CH_2CH_2CH_3\\ |\\ CH_2HO\end{matrix}$$

Normal Butyl Alcohol.



$$\begin{matrix}CH\left<\begin{matrix}CH_3\\CH_3\end{matrix}\right.\\ |\\ CH_2HO\end{matrix}$$

Isobutyl Alcohol.

In addition to isobutyl alcohol, amyl alcohol is also produced as a bye-product during the manufacture of alcohol from potatoes or grain. Amyl alcohol is an oily looking liquid, which does not mix with water, but with alcohol and ether in all proportions; it boils at 137° C. Amyl alcohol has a strong, disagreeable smell, and burning taste. Its intoxicating effects are similar to those of ethyl alcohol, but a small quantity of amyl alcohol suffices to produce all symptoms of intoxication; it has been estimated that amyl alcohol is fifteen times as intoxicating as is ethyl alcohol.

104. Fusel or Fousel Oil.—This name is applied to the oily mixture of spirits above referred to as being formed during fermentation. The fusel oil of potato and grain spirits principally consists of amyl alcohol.

105. Glycerin, $C_3H_5(HO)_3$.—In constitution this body is an alcohol, and may be regarded as the paraffin propane, C_3H_8, in which three of the hydrogen atoms have been replaced by three groups of hydroxyl. When pure, glycerin is a colourless, odourless, and thick sirupy liquid, having a sweet taste, and boiling at a temperature of 290° C. Glycerin is one of the substances produced during the normal fermentation of sugar, and also is the basic constituent of fats and oils.

106. Mannitol, $C_6H_8(HO)_6$.—This is a substance possessing a sweet taste and found in the sap of certain plants, which sap when dried constitutes what is known as *manna*. In constitution mannitol is a hexahydric alcohol, and is of interest from its relationship to the sugars and other carbohydrates. Mannitol is regarded as being derived from the paraffin hexane, C_6H_{14}, by the replacement of six atoms of hydrogen by six hydroxyl groups.

107. The Ethers.—These bodies are the oxides of the organic radicals: the most important is ethylic ether, or ethyl oxide, $\left\{\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right.O$. When the term "ether" is employed without any qualification, it is this body to which reference is made. From its mode of preparation, ether is often termed "sulphuric ether"; sulphuric acid, of course, does not enter into its composition. Ether is a colourless, very mobile liquid, having a peculiar, penetrating, and characteristic smell. This smell has given rise to the term "ethereal odour." Ether has a specific gravity of 0.736, it does not mix with water; but, on being added, forms a layer on the surface. The ether dissolves a certain quantity of water, while the water, on the other hand, holds a portion of the ether in solution. Ether boils at 34.5° C., and is very volatile at ordinary temperature. The vapour is inflammable; and, as may be gathered from the formula, is very heavy. Great care must be taken when working with ether to keep all lights at a safe distance. The high density of the vapour causes it to flow as a dense layer along a level surface for a considerable distance; in this way there is danger of the vapour communicating with a light that may be placed even at the further end of a long table. The rule should invariably be adopted of having no more of the liquid in the immediate neighbourhood, where experiments are being made, than is necessary for the purpose in hand; the store bottle should not be kept in the laboratory. Ether is of great use as a solvent for fats, resins, and other organic bodies.

108. Esters or Ethereal Salts.—These bodies are produced by the displacement of the hydrogen of acids by organic radicals; the acid may be organic or inorganic. The compounds of such radicals, with chlorine, bromine, and iodine, are at times viewed as a sub-class of these bodies, and are termed "haloid" esters. The esters were at one time called "compound ethers," but the newer name "ester" is now employed in order to differentiate them from the true ethers or oxides of organic radicals. The following are formulæ of examples of esters:—

C_2H_5Cl. Ethyl Chloride.	$C_2H_5C_2H_3O_2$. Ethyl Acetate.	$C_5H_{11}C_2H_3O_2$. Amyl Acetate.
$NaCl$. Sodium Chloride.	$NaC_2H_3O_2$. Sodium Acetate.	$NaC_2H_3O_2$. Sodium Acetate.

The corresponding sodium salts are written underneath in order to show their similarity in constitution. Amyl acetate is the confectioner's well-known jargonelle pear flavouring, while pineapple essence consists of another ester, ethyl butyrate, $C_2H_5C_4H_7O_2$.

On appropriate treatment with sodium hydroxide, the esters are split up with the formation of a sodium salt, thus:—

$$\underset{\text{Ethyl Acetate.}}{C_2H_5C_2H_3O_2} + \underset{\text{Sodium Hydroxide.}}{NaHO} = \underset{\text{Sodium Acetate.}}{NaC_2H_3O_2} + \underset{\text{Alcohol (Ethyl Hydroxide).}}{C_2H_5HO.}$$

The reaction is similar to that of sodium hydroxide on a weaker inorganic base, as ammonium:—

$$\underset{\text{Ammonium Chloride.}}{NH_4Cl} + \underset{\text{Sodium Hydroxide.}}{NaHO} = \underset{\text{Sodium Chloride.}}{NaCl} + \underset{\text{Ammonium Hydroxide.}}{NH_4HO.}$$

109. Chloroform, $CHCl_3$.—In a number of organic compounds it is possible to replace the atoms of certain elements present by those of others; in this way what are called "substitution products" are formed. Starting with methyl hydride, CH_4, the hydrogen of this body may be replaced atom by atom by chlorine until CCl_4 is formed. The replacement of three atoms of hydrogen by chlorine results in the production of chloroform, $CHCl_3$. This compound is at ordinary temperatures a heavy volatile liquid, having a specific gravity of 1.48. The vapour of chloroform has a peculiar but pleasant smell, and when inhaled produces insensibility to pain, while in less quantities it causes stupefaction. No danger need, however, be apprehended during any ordinary working with this substance. Chloroform boils at a temperature of 60.8° C. Chloroform, like ether, acts as a solvent of many organic bodies; it is only slightly soluble in water, and after being shaken up with that liquid more or less quickly subsides and forms a layer at the bottom.

110. Iodoform, CHI_3.—This is a yellow solid body, analogous in constitution to chloroform.

111. Organic Acids.—These bodies constitute a numerous class of organic compounds; like the radicals, they are capable of subdivision into distinct families, the members of which exhibit considerable resemblance to each other. Several of these groups of acids are derivatives from corresponding series of alcohols.

112. Fatty Acids, or Acids of Acetic Series.—These acids may be represented by the general formula, $\left\{\begin{matrix}C_nH_{2n}+1.\\COHO\end{matrix}\right.$ The lowest member of the series is formic acid, $\left\{\begin{matrix}H\\COHO\end{matrix}\right.$, or $HCHO_2$. The next and best known is acetic acid, $\left\{\begin{matrix}CH_3\\COHO\end{matrix}\right.$, or $HC_2H_3O_2$. Acetic acid is the derivative from ethyl alcohol. It will be of service to place side by side for comparison the formulæ of ethyl and some of its principal derivatives:—

$\left\{\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right.$ Ethyl.	$\left\{\begin{matrix}C_2H_5O\\C_2H_5\end{matrix}\right.$ Ethyl Oxide or Ether.

$$\begin{array}{ccc} C_2H_5HO, \text{ or } \left\{\begin{matrix}CH_3\\CH_2HO\end{matrix}\right. & \left\{\begin{matrix}CH_3\\COH\end{matrix}\right. & \begin{matrix}CH_3\\COHO\end{matrix} \\ \text{Ethyl Hydroxide or Alcohol.} & \text{Acetic Aldehyde.} & \text{Acetic Acid.} \end{array}$$

By oxidising agents, two atoms of hydrogen may be removed from alcohol with the formation of acetic aldehyde. This body is formed as an intermediate step between alcohol and acetic acid. Aldehyde readily combines with another atom of oxygen to form acetic acid. Further reference is made subsequently to the aldehydes as a class.

113. Acetic Acid.—This body is a liquid which boils at a temperature of 117° and freezes at 17° C.; it has a sharp but pleasant smell, and is well known in a dilute form as vinegar. Vinegar is manufactured by a species of fermentation from alcohol: its interest in connection with our present subject, lies in the fact that during many fermenting processes acetic acid is produced.

114. Butyric Acid, $\left\{\begin{matrix}C_3H_7\\COHO\end{matrix}\right.$, or $HC_4H_7O_2$.—This body bears the same relation to butyl alcohol that acetic acid does to that of ethyl. Butyric acid occurs in rancid butter, sweat, and many animal secretions. It is also one of the products of putrefaction, or putrid fermentation, of many organic substances; for instance, it may be formed in considerable quantity by the action of putrid cheese on sugar. Butyric acid is a liquid having a sharp odour resembling that of rancid butter.

115. The Higher Fatty Acids.—These have received their special name because of their occurrence as constituents of many natural fats; among those thus found are butyric acid (above described); palmitic acid, $\left\{\begin{matrix}C_{15}H_{31}\\COHO\end{matrix}\right.$, or $HC_{16}H_{31}O_2$; margaric acid, $\left\{\begin{matrix}C_{16}H_{33}\\COHO\end{matrix}\right.$, or $HC_{17}H_{33}O_2$; and stearic acid, $\left\{\begin{matrix}C_{17}H_{35}\\COHO\end{matrix}\right.$, or $HC_{18}H_{35}O_2$. These latter bodies are at ordinary temperatures fatty solids, melting into oily liquids with an increase of temperature. Physically, they bear little resemblance to acetic acid; but the formulæ at once show their similarity in constitution.

116. Fats and Soaps, or Salts of Higher Fatty Acids.—Most natural fats are salts of the higher fatty acids, with glycerin as the base; for example, mutton fat is essentially composed of the stearate of glycerin. This body may be artificially produced by heating together stearic acid and glycerin, according to the following equation—

$$\underset{\text{Stearic Acid.}}{3HC_{18}H_{35}O_2} + \underset{\text{Glycerin.}}{C_3H_5(HO)_3} = \underset{\text{Glycerin Stearate.}}{C_3H_5(C_{18}H_{35}O_2)_3} + \underset{\text{Water.}}{3H_2O.}$$

Some natural fats contain an excess of the fatty acid over and above that sufficient to combine with the whole of the glycerin present.

In addition to the "fatty" acids, acids of another group, known as the oleic series, are found as constituents of natural oils and fats. Oleic acid, $HC_{18}H_{33}O_2$, is the product of oxidation of an alcohol of the family $C_nH_{2n-1}HO$ series: it will be noticed that the formula of the acid differs from that of stearic acid by containing two atoms less of hydrogen: this difference follows from the difference in the typical formulæ of the two series of alcohols. The oleates of glycerin constitute the oils or liquid portions of fats.

By the action of alkalies, as soda or potash, the fats are decomposed, with the formation of sodium or potassium salts of the fatty acids, and the liberation of glycerin in the free state. These salts constitute the bodies known technically as "soaps," those of sodium are the "hard," and those of potassium "soft" soaps. The separation of fats into glycerin and the fatty acids may also be effected by forcing a current of steam through the melted fat. The glycerin distils over with the steam. This operation of decomposing fat by the aid of alkalies is termed "saponification," and, in addition to its great use in the commercial manufacture of soap, constitutes a valuable method of investigating the composition and properties of natural fats and oils.

Some few other organic acids of interest yet remain to be described: among these there is:—

117. Lactic Acid, $HC_3H_5O_3$.—This body occurs in sour milk, and is also produced in greater or less quantities during fermentation with ordinary commercial yeast. Lactic acid is a sirupy liquid of specific gravity 1.215, colourless and odourless, and having a very sharp sour taste. It forms a well-defined series of salts.

118. Succinic Acid, $H_2C_4H_4O_4$.—Succinic acid is a white solid body, soluble in water. It is one of the bodies produced during the normal alcoholic fermentation of sugar. On being heated, succinic acid evolves dense suffocating fumes.

119. Tartaric Acid, $H_2C_4H_4O_6$.—This body occurs naturally as a constituent of the juice of the grape, and in various other plants. It is when pure a white solid crystalline body, soluble in water, and possessing a pleasant sour taste. On being heated, tartaric acid evolves an odour of burnt sugar. Tartaric acid is dibasic, and forms both an acid and a normal series of salts, termed "tartrates." The well-known substance "cream of tartar" is acid potassium tartrate, $KHC_4H_4O_6$; this body has an acid reaction, and, like tartaric acid, decomposes sodium carbonate with the evolution of carbon dioxide gas. As, however, one-half the hydrogen has been already replaced in cream of tartar by potassium, that salt has only half the power, molecule for molecule, of decomposing sodium carbonate that is possessed by free tartaric acid. When acid potassium tartrate is neutralised by the addition of sodium carbonate so long as effervescence occurs, there is produced a double tartrate of potassium and sodium, $KNaC_4H_4O_6$. This body is soluble in water, and is known as "Rochelle salt."

120. Definition of Homologues, etc.—At this stage of the subject it will be convenient to explain the meaning which is attached to "homologue" and other similar terms used in describing organic bodies. **Series of bodies are termed homologous, in which their general constitution may be represented by a typical formula**; thus, the organic radicals of the methyl series are homologous, so too are the corresponding alcohols, and also the fatty acids. The melting and boiling points of the members of a homologous series usually rise as the series is ascended. When capable of being vapourised, their density in the gaseous condition increases with the ascent of the series. In many cases, the lower members of a series of homologues are more chemically active than are the higher members.

Many organic bodies are known which not only contain the same elements, but also contain them in the same proportion, while their physical and chemical character show them, nevertheless, to be distinct compounds. **Distinct compounds, having the same percentage composition, are said to be "isomers," or "isomeric with each other."** Isomerism may be of different kinds. Thus, bodies may have the same percentage composition, and yet have different molecular weights: in these cases the molecular weights are multiples of the simplest possible molecular weight that can be deduced from the percentage composition. **Bodies having the same percentage composition, but different molecular weights, are said to be "polymers," or "polymeric" with each other.**

The following are instances of polymeric bodies:—

Ethylene —C_2H_4.
Propylene—C_3H_6.
Butylene —C_4H_8.

In addition to isomerism of the above type there is yet another more striking variety. **When distinct chemical compounds have not only the same percentage composition, but also the same molecular weight, they are said to be "metamers," or "metameric" with each other.** As examples of metameric compounds, the following three bodies may be cited—propylamine, methylethylamine, and trimethylamine. These three bodies all have the formula NC_3H_9. That they are distinct compounds containing the same proportions of carbon and hydrogen, but united together to form different organic radicals, is seen when the formulæ are written as below:—

$$\begin{array}{ccc} N\left\{\begin{array}{l} C_3H_7 \\ H \\ H \end{array}\right. & N\left\{\begin{array}{l} CH_3 \\ C_2H_5 \\ H \end{array}\right. & N\left\{\begin{array}{l} CH_3 \\ CH_3 \\ CH_3 \end{array}\right. \\ \text{Propylamine.} & \text{Methylethylamine.} & \text{Trimethylamine.} \end{array}$$

The nature and constitution of these bodies are described in paragraph 127.

121. The Aldehydes.—One of the members of this group, acetic aldehyde, has already been mentioned in a previous paragraph; as explained, its preparation is effected by the removal of hydrogen from the corresponding alcohol. Hence the name aldehyde, derived from "*al*cohol *dehyd*rogenatum." The lowest aldehyde of the ethyl series is that derived from methyl alcohol according to the following equation:—

$$\underset{\text{Methyl Alcohol.}}{CH_3HO} = \underset{\text{Methyl or Formic Aldehyde (Formaldehyde).}}{HCOH} + \underset{\text{Hydrogen.}}{H_2}.$$

The oxygen of the aldehydes is directly united to the carbon, and is not present as hydroxyl as in the alcohols. This is shown in the comparative graphic formulæ given subsequently.

Formic aldehyde is a powerful and well-known disinfectant; its solution in water, termed formalin, is employed both as a disinfectant and preservative.

122. The Aldoses.—Closely allied to the aldehydes are the bodies collectively known as aldoses. Among these is hexose, which is an aldose containing six atoms of carbon, and having the formula

$$H_2COH.4HCOH.COH, \text{ or } C_6H_{12}O_6.$$

There are several hexoses, one of the number being the well-known sugar, glucose. Hexose and the homologous aldoses have formulæ which are multiples of that of formic aldehyde. They all contain the CO group.

123. The Ketones.—A group of substitution compounds is produced by the replacement of the hydrogen of an aldehyde by a radical of the ethyl series; thus acetone results from the substitution of methyl for hydrogen in acetic aldehyde:—

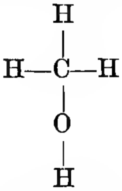
$$\underset{\text{Aldehyde.}}{CH_3COH.} \qquad \underset{\text{Acetone.}}{CH_3COCH_3.}$$

These bodies are called ketones, the name being derived from acetone. It will be observed that the independent CO group is still present. An important ketone is butyl-methyl ketone, of which the formula is $C_4H_9.CO.CH_3$.

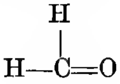
124. The Ketoses.—The ketoses may be regarded as ketones in which the hydrogen of the radical has in part been replaced by hydroxyl. By this replacement butyl-methyl ketone becomes the ketose, fructose or lævulose, of which the formula is

$$CH_2OH.CHOH.CHOH.CHOH.CO.CH_2OH.$$

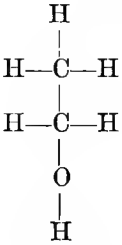
Lævulose is a form of sugar. The relationship of these various bodies to each other is of importance as throwing light on the chemical constitution of the sugars and other allied compounds, to which in subsequent chapters extended reference is made. The following graphic formulæ show how these bodies are related to each other.



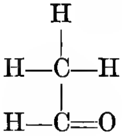
Methyl Alcohol.



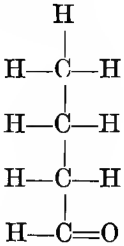
Methyl, or Formic, Aldehyde.



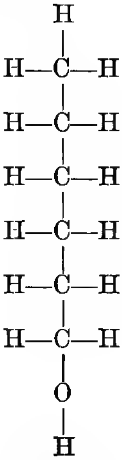
Ethyl Alcohol.



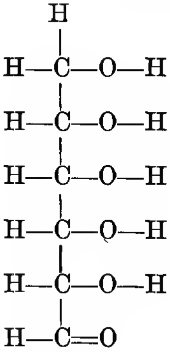
Acetic Aldehyde.



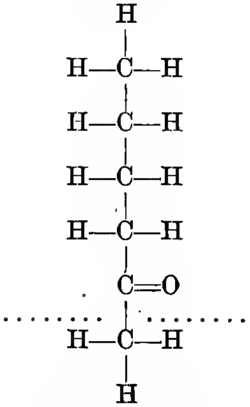
Butylaldehyde.



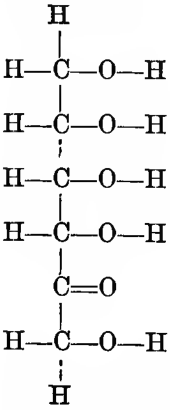
Hexylic Alcohol.



Hexose, Glucose.



Butyl-Methyl Ketone.



Lævulose (Ketose).

The relationship between methyl alcohol and its corresponding aldehyde is very simple, one atom of hydrogen and one group of hydroxyl are replaced by an atom of dyad oxygen. The same holds good with regard to ethyl alcohol and acetic aldehyde. An inspection of the formulæ shows that while in the alcohol the ethyl radical is intact and is combined with an extraneous group of hydroxyl, in the corresponding aldehyde the oxygen atom has made an inroad into the ethyl group and has replaced one of its atoms of hydrogen. The aldehyde is not that of the intact C_nH_{2n+1} radical, but that of the next higher member of the series. Similarly, butyl is C_4H_9, but butyl aldehyde is C_3H_7COH as shown in the graphic formula.

Coming next to the hexose as a member of the aldoses, the formula of hexylic alcohol is given beside it in order that the two types may be compared. In the case of five of the carbon atoms, an atom of hydrogen has been replaced by hydroxyl, while with the remaining carbon atom the same change has occurred as in the conversion of alcohols into aldehydes.

The formation of ketones is rendered clear by the before given formulæ of aldehyde and acetone. Turning to the more complicated ketones, the formula of butyl-methyl ketone is given, but the principle of the nomenclature is not quite the same. Butyl aldehyde is C_3H_7COH, in accordance with the rule of naming other aldehydes, but that part of the formula of butyl-methyl ketone above the dotted line which is on the pattern of the formula of an aldehyde, in composition reads C_4H_9CO—, that is to say, the butyl radical is intact with the aldehydic carbon atom added on to it. Following the same rule as in aldehydes generally, this would be regarded as the aldehyde of the next higher radical, amyl, C_5H_{11}. One must, therefore, regard these ketones as combinations of the group CO (carbonyl) with the intact radicals from which the name is derived.

In the ketoses, a portion of the hydrogen of the ketone is replaced by groups of hydroxyl, and examination of the formulæ shows the ketoses to bear much the same relation in composition to the ketones as do the aldoses to the corresponding alcohols.

125. Pentose and Pentosan.—Passing mention must be made of the pentose group of aldoses. These contain five atoms of carbon, the formula of pentose being $C_5H_{10}O_5$. By condensation with elimination of water, the pentoses furnish the corresponding pentosans thus:—

$$\underset{\text{Pentose.}}{C_5H_{10}O_5} = \underset{\text{Pentosan.}}{C_5H_8O_4} + \underset{\text{Water.}}{H_2O.}$$

These bodies are found in the woody fibre of the outer envelope of wheat, and by hydrolysis yield pentose sugars.

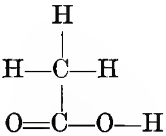
126. Nitrogenous Organic Bodies.—Many organic compounds, both from animal and vegetable sources, contain nitrogen as one of their constituents. The constitution of the majority of these bodies has not as yet been completely investigated; a large number of them are, however, basic in their character, and hence are known as nitrogenous organic bases, or "alkaloids."

127. Amines, Substitution, or Compound, Ammonias.—Many of the nitrogenous organic bodies are built upon the same type as ammonia, and may be viewed as ammonia in which one or more of the atoms of hydrogen are replaced by compound radicals. These compounds are termed "amines," or "substitution ammonias." The three bodies, propylamine, methylethylamine, and trimethylamine, whose formulæ are given in a preceding paragraph, are examples of amines. The methylamines are gases at ordinary temperatures, having a strong ammoniacal and fish-like smell. Trimethylamine is produced by decomposing proteins, and is the source of the characteristic smell of fish.

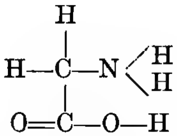
128. Alkaloids.—This name is applied to a class of organic bodies, most of which contain nitrogen, carbon, hydrogen, and oxygen. All these bodies are basic, while many are able to neutralise even the strongest acids, as sulphuric acid. They are, as a class, remarkably energetic in their action on animals; thus, quinine and morphine are most powerful medicines, while strychnine and brucine are among the most violent poisons; but little is understood of the constitution of the alkaloids; it is probable that they are of the same type as the compound ammonias. For the sake of uniformity in chemical nomenclature, it has been proposed to restrict the termination "ine" to the alkaloids; for this reason, glycerin, dextrin, etc., should never be written glycerine, dextrine, etc.

129. Amino-acids.—The amino-acids are bodies intermediate in character between an acid and a weak base, fulfilling under different circumstances the functions of either. They have no acid taste, do not redden litmus, and are derivatives from organic acids in which hydrogen of the acid radical is replaced by amidogen.

Among members of this group are glycine, or amino-acetic acid, $C_2H_5NO_2$, the relation of which to acetic acid is shown in the following graphic formulæ:—



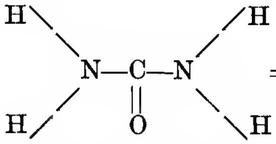
Acetic Acid.



Amino-Acetic Acid.

Aspartic acid, amino-succinic acid, $C_4H_7NO_4$, and glutamic acid, amino-glutaric acid, $C_5H_9NO_4$, are members of this group. So also are leucine, amino-caproic acid, $C_6H_{13}NO_2$, and tyrosine, amino-oxy-phenyl-propionic acid, $C_9H_{11}NO_3$. All these bodies are important constituents and decomposition products of the proteins. Leucine is soluble at 12° C. in 48 parts of water and 800 of alcohol; and insoluble in ether. Tyrosine dissolves in 150 parts of boiling water and is insoluble in alcohol and ether.

130. Amides.—Amides may be regarded as derivatives of acids in which amidogen, NH_2, replaces hydroxyl, HO; or they may be looked on as ammonia in which one or more of the hydrogen atoms are replaced by organic radicals. Urea, CON_2H_4, is a typical amide. It may be viewed as a derivative of carbonic acid, $CO(HO)_2$, in which case the two groups of HO are replaced by two groups of NH_2; or on the other hypothesis may be regarded as two molecules of ammonia, NH_3, with a pair of hydrogen atoms replaced by CO, thus:—

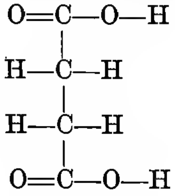


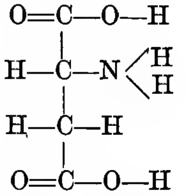
$= CON_2H_4$

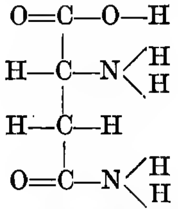
Urea, Carbamide.

The amides are distinguished from the amines by the latter being incapable of derivation in constitution from an acid.

Among amides found in plants are asparagine, $C_4H_8N_2O_3$, and glutamine, $C_5H_{10}N_2O_3$. Asparagine is the amide of amino-succinic acid. The relation between succinic acid, amino-succinic acid, and the amide asparagine is shown in the following formulæ:—

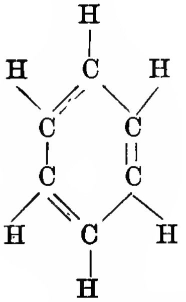

Succinic Acid.


Amino-Succinic Acid.


Asparagine (Amide).

The amides are crystalline, diffusible bodies. Asparagine is soluble in hot water, but not in alcohol or ether.

131. Phenylhydrazine.—Among the compounds of nitrogen with hydrogen is that known as hydrazine, N_2H_4. Further, there is a compound of hydrogen and carbon named benzene, C_6H_6. This body is regarded as a combination of a radical, phenyl, C_6H_5, with hydrogen. The generally accepted view of the composition of the bodies of this group is that suggested by Kekulé, who regarded the carbon atoms as forming a closed chain, as shown in the following formula:—


Benzene or Phenylhydride.

If one of the atoms of hydrogen in hydrazine be replaced by phenyl, C_6H_5, phenylhydrazine is produced, and has the formula, $C_6H_5NHNH_2$. This body is of importance because of the great value it has been in the investigation of the composition of the sugars.

132. Phenylhydrazones or Hydrazones.—Phenylhydrazine is capable of entering into combination with aldehydes, aldoses, ketones and ketoses, in the proportions of one molecule of each with the elimination of a molecule of water. The bodies thus produced are termed phenylhydrazones. or more briefly, hydrazones. The formation of two of these bodies is shown in the following equations:—

$$\underset{\text{Aldehyde.}}{CH_3COH} + \underset{\text{Phenylhydrazine.}}{N_2H_3C_6H_5} = \underset{\text{Aldehyde-hydrazone.}}{CH_3CN_2H_2C_6H_5} + \underset{\text{Water.}}{H_2O.}$$

$$\underset{\text{Hexose, Glucose.}}{H_2COH(HCOH)_4COH} + \underset{\text{Phenylhydrazine.}}{N_2H_3C_6H_5} =$$

$$\underset{\text{Glucose-hydrazone.}}{H_2COH(HCOH)_4CN_2H_2C_6H_5} + \underset{\text{Water.}}{H_2O.}$$

The hydrazones occasionally serve as means of identifying sugars, but are far exceeded in value for that purpose by the compounds described in the next paragraph.

133. Phenylosazones or Osazones.—When an aqueous solution of either an aldose or ketose is heated together with phenylhydrazine acetate in the proportion of one molecule of the former to three molecules of the acetate, a somewhat complicated reaction ensues. Among its products is a compound consisting of two molecules of phenylhydrazine with one of the aldose or ketose, which body is a phenylosazone, or more shortly osazone. Taking the example of glucose, the following is the formula of the phenylglucosazone:—

$$\underset{\text{Phenylglucosazone.}}{H_2COH(HCOH)_3CN_2HC_6H_5CN_2H_2C_6H_5.}$$

Two groups of phenylhydrazine have become incorporated in the molecule of glucose with the elimination of two molecules of water. There are other secondary chemical changes which need not be further described. The osazones have well marked chemical characteristics in the direction of opticity and other properties. These are of great service in identifying particular sugars, the *modus operandi* being to prepare the osazone, and then through the properties of this body to identify the sugar.

CHAPTER IV.

THE MICROSCOPE, AND POLARISATION OF LIGHT.

134. Object of Microscope.—A description of the microscope, and method of using it, is given at this early stage, because the student will continually find it requisite to have recourse to this instrument from time to time, while going on with his study of the chemical properties of the various grain constituents. In order to thoroughly understand the physical construction of bodies it is necessary to *see* them. The microscope is an instrument to enable us to see points of physical construction which are so minute as to escape the unaided vision.

135. Description of Microscope.—The demand for good microscopes has led to the supply by a number of makers of really excellent instruments. In consequence, the microscope is not now, even to the general public, an unfamiliar piece of apparatus. These pages are not the place where an exhaustive description of microscopes could with fitness be given, but as the instrument should be in the hands of every miller and baker, a few hints as to how to use it for such purposes as those occurring during milling and bread-making will naturally find a place in this work.

Every reader will probably be familiar with the general appearance of the instrument as shown in the illustration. The microscope proper consists of the stand, to which is attached the main tube of the instrument, by means of a sliding "dove-tail" arrangement, that can be raised or lowered by a rack and pinion: the pair of milled heads, D, actuate this pinion. Below is another pair of milled heads, E, which are more delicate in their action, and constitute what is known as the "fine adjustment." The stage, G, is that part of the instrument arranged for the reception of the object being examined. It consists of a flat surface at right angles to the axis through the tube of the microscope, and carries on it a pair of spring clips, F, by means of which the glass on which the object is mounted is held on the stage, G, and thus may be shifted in any direction by the fingers. Underneath the stage is a contrivance known technically as the sub-stage, H: this is also fitted with a rack and pinion, and may be raised or lowered by the milled head, I. The central aperture of the sub-stage is arranged to take either a sub-stage illuminator (Abbé condenser), a series of diaphragms, the polariser of a polarising apparatus, or other desired sub-stage fittings. Beneath this again is a concave glass mirror, J, so mounted as to be easily placed in any required position. The tube of the microscope, together with the stage and mirror, can be turned at any angle to the tripod stand, from the vertical to the horizontal. Within the main tube is fitted a second, B, known as the "draw tube," which can be pulled out if required, thus increasing the distance between the eyepiece and object glass. A scale is engraved on the side of the draw tube, by which the amount of withdrawal can be observed and noted. The lower end of the main tube is provided with an internal screw at C, for the purpose of receiving the combinations of lenses known as "object glasses," or "objectives." The objectives of all the best makers are now cut with the same screw thread, and so are interchangeable. The "eyepiece," A, also a lens combination, slides into the top of the draw tube.

The objectives are named according to their focal length, and are consequently termed "1-in. objectives," etc. One of these is shown in position at L. The greater the focal length, the less is the magnifying power of an objective. The eye-pieces also vary in magnifying power, and are usually referred to as "A," "B" eye-pieces, and so on; the magnification increases with each successive letter of the alphabet, commencing with A. The student will require a series of objectives, consisting of the 2-inch, 1-inch, and ⅛-inch; these will be found to answer most purposes, although for bacteriological work a 1/12-inch oil immersion objective in addition is exceedingly useful. In working with a microscope it is frequently necessary to change from a high to a low magnifying power. In

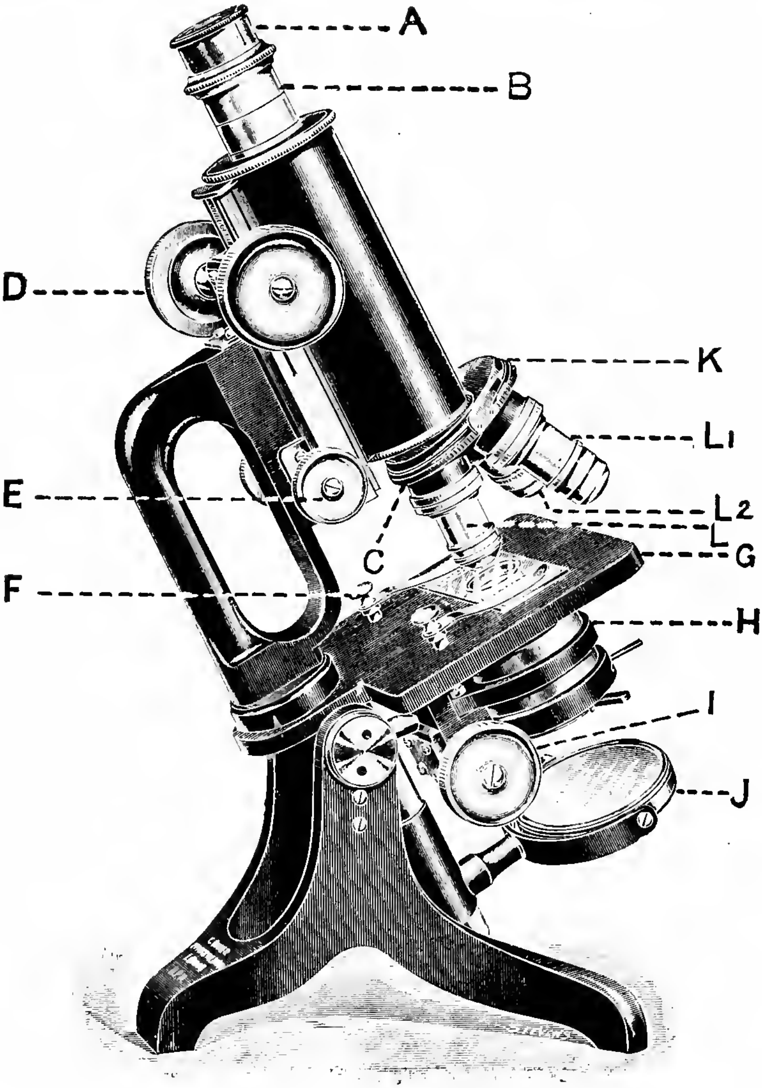


Fig. 2.—The Microscope.

order to do this rapidly, microscopes are now provided with a carrier, K, which screws into the tube at C, and to which a number of objectives, L, L1, L2, is attached. By rotating this carrier the various objectives may be quickly exchanged for each other. In the following description it will be assumed that the instrument is fitted with such a carrier. For ordinary work the A eye-piece is sufficient, but a C eye-piece is also at times useful. The following accessories are requisite: one or two dozen glass slides, 3 inches by 1; some thin glass covers—these may be round or square, and should be about 5/8 inch diameter, or square; a pair of fine forceps; one or two needles set in handles; a glass rod drawn out to a point at one end, and a small piece of glass tubing. All these may be obtained from the maker of the microscope, and are usually supplied in the case with the instrument. Other useful pieces of additional apparatus will be mentioned as necessity arises for their employment.

A word may be said in the first place about the preserving of the instrument from injury. When not in use it should either be kept in its case, or, what is more convenient, under a glass shade, as then it can be readily used when required. A mounted longitudinal section of a grain of wheat should be purchased at the same time as the instrument; this is a very useful slide to possess, and will give the student an opportunity of learning how to use his microscope before he proceeds to mounting objects for himself.

136. How to Use the Microscope.—To commence using the instrument, remove it from the case, take the 2-inch objective out of its box and screw it into the bottom of the tube; next insert the eye-piece in its place. The lenses, if dusty, may be very gently wiped with either an old silk handkerchief that has been often washed, or a piece of wash-leather. One or other of these should be kept solely for this purpose. The less, however, that the lenses require wiping the better, as, being made of soft glass, they easily scratch. When working on yeast, temporarily mounted in water or other liquid substance, it is necessary to set the stage horizontal, as otherwise the liquid flows downward. But with fixed and permanent objects, the microscope should be inclined to an angle of about 45 degrees, as in such a position the eye is much less fatigued during observation. The next requisite is light. In the daytime choose a room that is well lighted, if possible not by direct sunlight, but by a bright cloud. At night an incandescent gas burner, especially if enclosed in a ground glass globe, makes a good source of light. Raise the microscope tube by turning the pinion, by means of the milled head, D, until the end of the objective is about 2 inches from the stage. Place the mounted wheat grain slide on the stage, and arrange the clips to hold it firmly. Next turn the mirror so as to throw the spot of light on the object. Now look down the eye-piece and lower the microscope tube until the object is focussed; that is, until its outlines are seen clearly without being blurred. A word may here be said about the amount of light advisable; generally speaking, the rule may be laid down that it is wise to work with no more light than necessary. The light should not be bright enough to dazzle the eye in the slightest degree; on the other hand, it should be sufficient for the object to be seen comfortably. The 2-inch objective will show the greater portion of the grain of wheat occupying the whole of the field of vision. Any object when seen through the microscope is inverted; that is, the top is seen at the bottom, and the left side at the right. By pulling out the draw tube the object is still further magnified.

In the next place rotate the carrier so as to substitute the 1-inch for the 2-inch objective. The microscope tube will now have to be lowered until the object is again in focus. A smaller portion only of the wheat-grain is seen in the field, but that portion is magnified to a much greater degree.

The illumination is much less than with the 2-inch object glass. Notice that more of the details of the object can be distinguished.

The 1/8-inch objective may now be tried. Unless the section is a very thin one, it will not, however, show up well. Having exchanged the inch for this power, lower the microscope tube until the end of the object glass is within an eighth of an inch from the slide; then move the milled head D, very slowly and carefully, watching all the time until the object is again in focus: for this purpose it is well to move the slide until a portion of the skin of the grain is in view. The milled head, E, may now be used for making the final adjustment of the focus. This latter milled head is termed the "fine adjustment," while that by means of the rack and pinion is spoken of as the "coarse adjustment." For the lower powers the coarse adjustment is sufficient.

This exercise with the three powers will have shown the student the mode of using his microscope. He must accustom himself to moving the object about on the stage, so as to get any portion he wishes in view; this presents some little difficulty at first, because the movement must be made in the opposite direction to that in which it is desired that the magnified image shall travel.

Any experimenting with the oil or water immersion objective had better be postponed until the student arrives at the stage of examining bacteriological specimens.

137. Measurement of Microscopic Objects.—The microscope is not merely used for the purpose of seeing small objects, but, with the addition of certain accessories, is also employed for measuring their size. The first object requisite for this purpose is a "stage micrometer"; an eye-piece micrometer should also be procured. The stage micrometer may consist of a fraction of an inch further divided up into tenths and hundredths, or preferably of a millimetre similarly graduated. The scale for this purpose is accurately photographed on a glass slip, the same as an ordinary slide. It will be remembered that the millimetre is very nearly the twenty-fifth part of an inch, consequently the tenth or hundredth of a millimetre may be taken as equal to the two hundred and fiftieth, or two thousand five hundredth part of an inch. Working with low powers, it is sufficient for rough purposes to place the stage micrometer face downwards on the object to be measured, and then to read the number of divisions of the micrometer over which the object to be measured extends. This can only be done with powers sufficiently low to permit the lines on the micrometer, and the object under examination, to be in focus, or nearly so, at the same time. The eye-piece micrometer is, for all purposes, far preferable. This instrument consists of a scale engraved on a circular piece of glass, as shown in Fig. 3, which is fixed in a specially adapted eye-piece, also figured. The top of the eye-piece draws out, and the micrometer scale is dropped in, so as to rest on the diaphragm shown

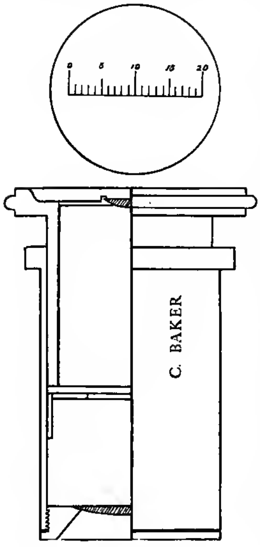


FIG. 3.—Eye-Piece Micrometer.

in section midway of the eye-piece. The figures, of course, must be uppermost, so as to read rightly on looking down the microscope. The scale being in position, the sliding tube of the eye-piece itself is drawn up or down until, on looking through it, the graduations are sharply focussed. With the eye-piece in position, on looking down the microscope, both the eye-piece scale and the object are seen in focus together. The scale looks as though it were simply superposed on the object. The value of this scale varies with each different power employed, but may be determined in the following manner—place the lowest power into position on the microscope; put the stage micrometer on the stage, and read off carefully in tenths and hundredths of a millimetre the value of one division of the eye-piece micrometer. Next repeat the same measurement in exactly the same way with each of the other objectives. In these determinations the draw tube must invariably be in the same position; it is best to have it always closed when the microscope is being used for measuring purposes. Thus, for example, with one of the microscopes in the possession of the authors one division of the eye-piece has the following values with different objectives:—

Objective.	M.m.	M.k.m.	Inch.
AA, Zeiss	0.0286	28.6	0.00126
A ,,	0.01734	17.34	0.00068
DD, ,,	0.004098	4.098	0.00016
One-twelfth oil immersion.	0.001265	1.265	0.00005
One-twentieth ,, ,,	0.001087	1.087	0.000043

Supposing that an object, under examination with the highest power, on being measured is 3.2 eye-piece divisions in length, then its real length is $0.001087 \times 3.2 = 0.00348$ m.m., or 0.000137 inch.

138. The Micromillimetre.—When the dimensions of minute objects are expressed either in inches or in millimetres they require such a number of figures that it is difficult to at first realise the value of the dimension. It has therefore been proposed to employ the one-thousandth part of a millimetre as a unit of length for microscopic measurements. This unit is called a micromillimetre, for which the following abbreviation, "mkm.," may be used. The mkm. is also sometimes called a "μ" (pronounced *mu*); its value in inches is very nearly 1/25400 inch. The eye-piece measurements given in the preceding paragraph have also their values expressed in micromillimetres.

139. Magnification in Diameters.—There remains to be explained a convenient method of measuring the magnifying power of objectives and eye-pieces. A common method of expressing the value of particular combinations of these two is to say that they magnify so many diameters. A moment's reflection will show that the image seen with a microscope will vary in actual dimensions, according to whether it be supposed to be near to or far from the eye. The only real measurement, in fact, is the visual angle it subtends. This being the case, the measurement in diameters is always expressed with the understanding that the object is supposed to be ten inches from the eye.

Here for a moment a slight digression must be made. Most beginners when looking through a microscope close the eye not in use. This is a bad plan, as the eyes are thereby much more fatigued. Both eyes should be kept open. At first the surrounding objects are continually being seen with the unoccupied eye, and it is apparently a hopeless case to see the object under the microscope at all. Practice overcomes this, but the authors have found the best plan is to fix to the microscope tube a piece of dead black cardboard, so that the unoccupied eye sees only a black surface. The object will now be observed with the greatest readiness, and probably not one quarter the fatigue. In a very short time the cardboard shield may be dispensed with, and the trained eyes so behave that the one is transmitting the view of the microscopic object to the brain, while the other is remaining idle and resting. The student should accustom himself to use either eye indifferently; he will soon find that he will no more think of closing one eye when looking through his microscope than he would of tying his left hand behind his back before he shakes hands with his right.

Now, the object of our momentary departure will be evident; the idle eye can, at will, be used for looking at something else, so that the one eye is looking at the microscopic object, the other, if wished, at say a piece of paper. Place the stage micrometer in focus, and fix a piece of stiff paper or cardboard as near as possible to the microscope, at right angles to its axis, and ten inches from the eye-piece. Look down the tube with the one eye, and with the other at the piece of paper. The magnified micrometer scale appears as though drawn on the paper. Still using both eyes, trace with a pencil on the paper the exact position of each line representing the tenths or hundredths of the millimetre. Next measure on the paper the distance between the two marks traced from, say, the tenths of a millimetre; suppose that this distance is five millimetres, then that particular combination of eye-piece and objective has a magnifying power of fifty diameters. Measure each other combination possible with the various eye-pieces and objectives in your possession in the same way.

140. Microscopic Sketching and Tracing.—The above method of measuring is very useful, because with small objects occupying a portion only of the field, it is possible to trace them on the paper in the manner described, and such tracings are then known to be magnified to the extent ascertained by previous measurement as directed. Such sketching by actual tracing is very desirable in microscopic work, as otherwise the student is extremely likely to draw an object either too large or too small; this is to be avoided, as one object of microscopic examination is to definitely ascertain the size of objects. It is the authors' practice when working without sketching to note the measurements with the eye-piece micrometer. When sketching they make tracings of sufficient at least of the object to give its actual dimensions, but a process similar in principle to that already described.

141. Camera Lucida.—For tracing with the microscope an appliance has been invented, which is known as a "camera lucida"; there is also a modification termed a neutral tint camera. An ingenious combination of eye-piece and camera lucida in one piece of apparatus is shown in section in Fig. 4. The principal portion of the figure consists of the ordinary eye-piece, *a, b,* with its upper and lower lenses, *c, d*; the central dotted line, *e, f,* is the direct axis of vision through the microscope. At the top right hand of the figure is a glass prism, *g,* of peculiar shape. The angles of this are so arranged that a ray of light, passing in the direction *h, i,* is totally reflected at *i,* in the direction *i, k,* and again at *k* is totally reflected in the line *k, l.* The result is that the eye placed over the aperture of the eye-piece, at *m,* receives both rays of light, *f, e,* and *h, i, k, l,* which enter the eye parallel to each other. In consequence, the eye sees simultaneously with the object under the microscope any other object placed in the direction of the line *i, h;* both are combined and appear to be in the direct line of vision through the instrument. Consequently if a sheet of paper be placed under *i, h,* it and the microscope image appear to the eye to coincide.

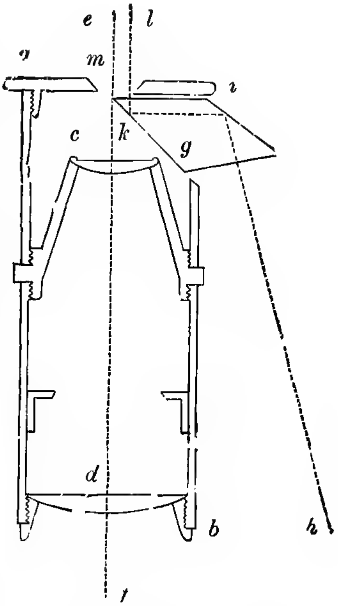


Fig. 4.—Combination of Eye-Piece and Camera Lucida.

When wishing to use the camera, place the microscope in a vertical position, directly facing the source of light, and turn the camera so that the prism, *g,* is at the right-hand side (as figured). Procure a box or other convenient stand of such a height that its upper surface, when placed beside the microscope, is of the same height as the microscope stage. Place this box on the right-hand side of the instrument, under the prism, *g,* so that the line, *i, h,* points to it. For drawing purposes the most convenient arrangement is a small drawing "block" of hot pressed paper, sheet after sheet of which can be removed as finished. Place this on the stand, under *i, h,* and look through the instrument; both object and paper should be seen in combination; that is, the image should appear to be superposed on the paper. To properly get this effect the paper and image should, as nearly as possible, be equally illuminated. As the paper is usually brighter than the image, provision is made for cutting off some of the light from it by introducing plates of neutral tinted glass in the path of *i, h,* just below the prism *g.* On the other hand, the illumination of the object may be adjusted by means of the reflecting mirror of the microscope.

As a preliminary to tracing with the camera, place the stage micrometer in focus, and the microscope and paper in their respective positions. Then, by means of a pencil, mark on the paper the length of the millimetre or fraction of the millimetre, and calculate out once for all the magnification in exact number of diameters. This is very easily done, as the lines of the object appear to be drawn on the paper; the pencil point being also seen, the operation of tracing simply consists of going over lines apparently already on the paper. With the same powers and eyepieces, and microscope and paper in the same relative positions, the magnification is always the same. In actual sketching it is usually sufficient to trace in the principal outlines; the details may then be added with sufficient accuracy by the ordinary method of judging dimensions by the eye, as in freehand drawing.

142. Microscopic Counting: the Hæmatimeter.—For certain purposes it is highly important to be able to count the number of small solid particles suspended in a fluid. Among them is the counting of blood corpuscles, and of yeast cells suspended in water or fermenting liquid. An instrument was first devised for this purpose, in order to count blood corpuscles, and hence is called a hæmatimeter; the same appliance is adapted to the counting of yeast cells, and is illustrated in Fig. 5. The instrument consists of a stout glass slide, on which is cemented a cover-glass with a circular opening, thus constituting a cell. On the glass slide, and in the centre of this cell, is arranged a raised circle of glass, on which is engraved a series of lines at right angles to each other, thus marking its surface off into a number of squares. A representation of this part of the apparatus is given on the left of the figure, showing its appearance when viewed through the microscope. Each of the larger squares has an area of $^{1}/_{400}$ (0.0025) square millimetre. The inner circle of glass, and the outer glass, are so arranged that the former is exactly $^{1}/_{10}$ m.m. the thinner; so that when the cover-glass is brought down into absolute contact with the outer glass, the space between the lower surface of one and the upper of the other is exactly 0.1 m.m. in thickness. Therefore the cubic contents of the space above each square on the inner glass is

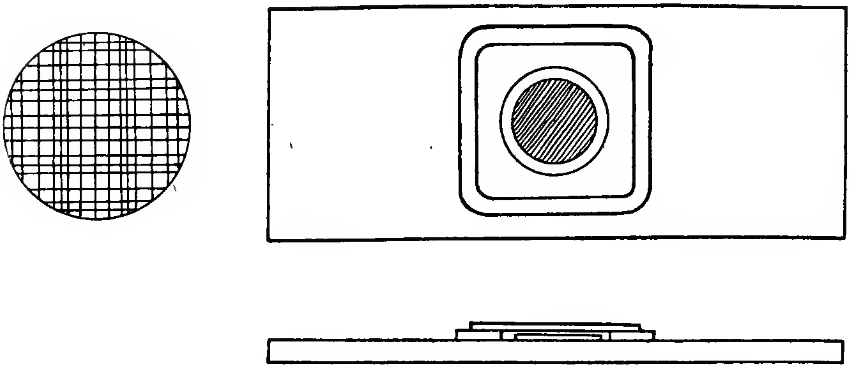


FIG. 5.—The Hæmatimeter.

$$0.0025 \times 0.1 = 0.00025 = {}^{1}/_{4000} \text{ cubic m.m.}$$

To perform a counting operation on yeast, for example, an average sample must be taken, diluted, and shaken up until the cells are uniformly distributed through the liquid. Hansen considers that the liquid most suitable for this purpose is dilute sulphuric acid, 1 part to 10 of water: for yeast the authors prefer to employ 1 part sulphuric acid, 1 part glycerin, and 8 of water. The viscid nature of the glycerin enables the liquid to keep the cells uniformly suspended through it for a longer time. The method of employing the hæmatimeter is best explained by giving an actual example. From a sample of compressed yeast, 0.25 gram was weighed off and made up to 50 c.c. with dilute glycerin and sulphuric acid. The yeast was broken down and thoroughly mixed with the liquid by violent shaking for some time in a flask. A droplet was then removed by means of a pointed glass rod, and placed on the centre of the glass of the hæmatimeter, and immediately covered with the cover: this is held in close contact either by a pair of small spring clips or by a weight put on. (The minute drop for this purpose must not be more than sufficient to nearly fill the space between the two glass surfaces: it must not be enough to run over into the outside annular space.) The apparatus is placed aside in a horizontal position to rest sufficiently long for the suspended cells to fall to the bottom of the layer of liquid. The yeast cells having settled down, say in ten minutes, place the hæmatimeter on the horizontal stage of the microscope, and prepare to commence counting, using about 1/6 inch objective (Zeiss D). The yeast cells will be seen lying on the engraved squares, some within the squares, and others directly on the dividing lines. Commence counting the cells within the top left-hand square, and make a note of the number, then go on along the line, come back, and count those on the squares of the next line, and so on. The cells lying on the lines must also, of course, be counted, but only once; that is, all lying on the horizontal lines must be counted in the squares above them and all on vertical lines in the squares to the right of them. The counting must be continued until a sufficient number of squares have been taken to give a true average. By experiment it should be ascertained how many squares must be counted in order that an additional number has no influence on the average obtained. It is usually sufficient to count some 50 or 60 of the squares. It is convenient to have the liquid of such a degree of dilution that about 8-10 cells occur in each square. Approximately the accidental errors amount—

by counting 200 cells, to 5 per cent. of the total result,
„ 1250 „ 2 „ „ „
„ 5000 „ 1 „ „ „

In the experiment being described, 100 squares were counted and contained 738 yeast cells.

Now the space above each square = 0.00025 cubic mm.
Therefore 100 spaces = 0.025 cubic m.m., and contain 738 cells.
Therefore 4000 spaces = 1.000 cubic m.m., and contain 7.38 × 4000 = 29,520 cells.
Therefore 1 c.c. = 1000 cubic m.m. and contains 29,520 × 1000 = 29,520,000 cells.
But 1 c.c. contained 0.005 gram of yeast, and therefore 1 gram contains 29,520,000 × 200 = 5,904,000,000 cells.
But 1 lb. avoirdupois = 453.59 grams, and therefore 1 lb. of the yeast contained:—
5,904,000,000 × 453.59 = 2,677,995,360,000 cells.

The smaller grained starches may also be counted in the same manner.

143.—The methods of using the microscope having been briefly described, directions for its use for special purposes will be given as occasion arises. For fuller descriptions of the instrument itself, its accessories and the method of using them, the student is referred to one of the many excellent works already published on the subject.

144. Polarisation of Light.—There are many substances which exert a special action on "polarised light"; among these are a variety of crystalline compounds, and certain organic bodies. It will be necessary at this stage to give a short description of the nature of a ray of light, and the way in which its character may be altered by the action of these substances just mentioned. As is well known, light travels in straight lines called rays. The actual motion of such a ray of light is somewhat like to that of a sea wave, or the ripples produced on the smooth surface of a pond by throwing a stone therein. In waves, the water itself does not move forward, but only the undulating motion of the surface; this is readily seen by floating a cork on the water; each little wave in its passage onward simply raises and depresses the cork, but leaves it in the same position as it found it. Light, then, also travels in waves, these waves being undulations in a substance filling all space, and known by the name of "ether." The waves of light differ remarkably in one particular from those on the surface of water; the undulatory motion in the latter is simply up and down, or, to use the scientific term, in a vertical plane. If the actual movements of the ether in a ray of light could only be rendered visible, a much more complicated motion would be perceived. Just as in the case of the water wave, the particles would move across, or transversely to, the direction of the path of the ray. Some of the particles would rise and fall like those in the water wave, but others would swing from side to side, or horizontally instead of vertically; further than this, others again would vibrate at every intermediate angle. This condition of things is expressed in the statement that the undulations of a wave of light are in a plane transverse to the path of the ray, and that the ether particles vibrate in every direction in that plane.

For our present purpose it will be sufficient to regard the wave of light as composed of two sets of vibrations, the one vertical, and the other horizontal, and therefore at right angles to each other; the intermediate vibrations may be ignored. The character of the undulations of a wave of light is not greatly altered by passing through glass, water, and many other bodies; the same does not, however, hold good with all transparent substances—of these one of the most striking is a mineral named tourmaline. Let two thin plates be cut from a crystal of this substance in a certain direction; on examination each is seen to be fairly transparent. Let one be placed over the other, and then slowly twisted round. In one particular position light passes through them both as readily as through either taken singly; but as one of the pair is turned round, less and less light is transmitted; until, when it has been rotated through an angle of 90 degrees, no light whatever passes. As the revolution is continued, the plates allow more and more light to pass; until, when an angle of 180 degrees has been reached, the combination of two plates is again transparent. A further revolution of 90 degrees once more causes opacity. This peculiar effect is due to the fact that tourmaline plates, such as described, permit the passage through them of only the vibrations of light in one plane, so that **the ray of light, after passing through the tourmaline, instead of having its vibrations in all directions of the plane, has them occurring in one direction only; the ray may then be compared to a water wave. Such a ray of light is said to be "polarised," and the change effected is termed the "polarisation of light."**

The tourmaline plate may be compared to a sieve composed of a set of wires in but one direction. Using this similitude, only those vibrations which are in the same direction as the wires of the sieve succeed in effecting a passage. The second tourmaline plate being set so that its wires are parallel to those of the first, the light which passed through the one succeeds also in passing through the other. But when the second tourmaline is turned at right angles to the first, then the light which passed through the one is cut off by the other, and so the two together refuse to transmit any light whatever.

Persons who are acquainted with the beautiful mineral known as Iceland spar, know that when a single dot is looked at through a piece of the spar, it is seen double; this is due to the fact that the spar splits the ray of light into two distinct rays; further, the light of each of these subrays is polarised in such a manner that the plane of polarisation (that is, the direction in which the vibrations occur) of the one ray is at right angles to that of the other. When pieces of Iceland spar are cut and rejoined in a particular manner, as shown by the oblique line in Fig. 6, they

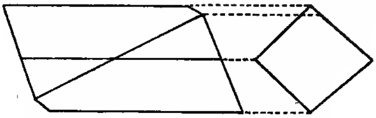


FIG. 6.—Nicol's Prism.

transmit the one only of these two rays, the other being lost by internal reflection within the crystal. Such pieces of spar are termed "Nicol's prisms," and may be used for the same purpose as the tourmaline plates; they have the great advantage of being composed of material as transparent as glass, while the tourmaline is usually only semi-transparent, apart from its polarising properties. The first Nicol's prism placed in the path of a ray of light is termed the polariser, because it effects the polarisation; the second is known as the analyser, because it enables us to determine the direction of the plane of the polarised ray. The attachments for a Nicol's prism are shown in Fig. 7, which is an illustration of the polariser and analyser of a microscope. The polariser, in use, is fitted to the sub-stage, and the analyser to the eye-piece.

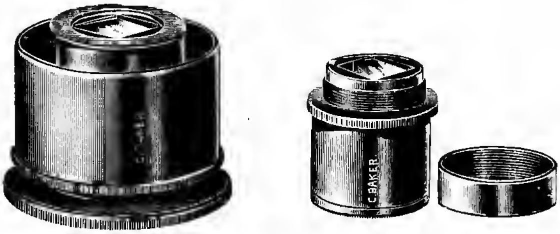


Fig. 7.—Polariser and Analyser of Microscope.

Returning again to the similitude of the sieves, suppose that, with the two at right angles to each other, it were possible to take the light after it had passed through the one, and was thus polarised, and twist or rotate its plane of polarisation through an angle of 90° before it came to the second, it would evidently then be able to pass through that also. Certain substances possess this remarkable property: among those of immediate interest in connection with the present subject are starch, sugar, and other of the carbohydrates. It is further found that while some compounds twist the polarised ray to the right, or in the direction of the hands of a watch, others rotate polarised light to the left. If two Nicol's prisms were so arranged as to give absolute darkness, and then a plate of sugar were placed between them, light would be transmitted. If the analyser were next turned around in a right-handed direction, the point of absolute darkness would again be reached, and then by measuring the angle of rotation, the number of degrees through which the plane of polarisation of light had been rotated by the sugar could be ascertained. Instruments are constructed for the purpose of making this measurement with great delicacy, and are termed "polarimeters." The exact point at which maximum light and darkness is reached during the rotation of the analyser cannot be observed with great accuracy; recourse is therefore had to observing some of the other characteristics of polarised light more easily detected by the eye. In the analytic section of this work, an explanation is given of the principles which guide chemists in the application of the rotation of the plane of the polarisation of light by sugar and other bodies to their estimation; a practical description then follows of one of the best forms of polarimeter and the method of using it. For microscopic purposes a polariser is fitted underneath the stage, and an analyser either within the body of the tube or over the eye-piece. The object under examination is thus illuminated by polarised light. For further information on the polarisation of light, the student is referred to Ganot's, or some other standard work on physics.

CHAPTER V.

CONSTITUENTS OF WHEAT AND FLOUR.

MINERAL AND FATTY MATTERS.

145. Construction of Wheat Grain.—Having given a brief outline of the principles and theory of Chemistry, in so far as they are more or less connected with the present subject. our next object must be to describe the chemical properties of the different compounds found in the grain, and to trace them out in the history of the flour and offal. The "cereals," to which wheat belongs, is the name given to the grasses which have been cultivated for use as food. The grain, as is of course well known, is the seed of the plant; although not strictly chemical information, it will be well to give here a short description of its various parts. The most important portion of the seed is the embryo or germ; this, which is a body rich in fatty matters, is that part of the seed which grows into the future plant. The interior of the seed contains a quantity of starch and other compounds, designed for the nutrition of the young plant during its earliest stages of growth. The whole is enclosed in an envelope, made up principally of woody fibre, and arranged in a series of coats, one outside the other, somewhat like those of an onion, only on a much finer scale. During the process of milling, the grain is divided into flour and what is technically known as offal. This latter substance, or group of substances, includes the germ, bran, pollard, etc. The bran and pollard are the different skins of the grain broken up into fragments of various sizes. This department of the subject will be dealt with fully in a subsequent part of the work.

146. Constituents of Wheat.—A large number of chemical compounds may be obtained from grain: these naturally divide themselves into Mineral or Inorganic Constituents, and Organic Constituents. The inorganic portions of wheat consist of water and the mineral bodies found in the ash. The organic compounds may be conveniently grouped into —fatty matters, starch, and allied bodies having a similar chemical composition, and nitrogenous bodies or proteins. Of these substances the fats have the simplest composition, next come the starchy bodies, and lastly, the proteins, whose constitution is extremely complex.

147. Mineral Constituents.—The properties of water are already sufficiently described; the actual amount present in grain varies from about 10 to 15 per cent. In sound wheats and flours there is no perceptible dampness, the water being chemically combined with the starch, which body probably exists in grain as a hydroxide. The other mineral constituents are usually obtained by heating the powdered grain to faint redness in a current of air; the organic bodies burn away and leave an ash consisting of the inorganic substances present. The ash of wheat has been made the subject of prolonged investigations and research, conducted principally, however, from an agricultural point of view. Land being impoverished by the growth of crops, the constitution of the ash of wheaten grain and straw is an indication of what mineral matters are removed from the soil by wheat crops, and therefore also affords information as to what additions have to be made to an exhausted soil in order to replenish its necessary mineral components. Lawes and Gilbert have from time to time published elaborate tables of results obtained on their experimental farm at Rothampsted; the following table is abstracted from a communication of theirs to the Chemical Society (*Chem. Soc. Jour.*, vol. xlv., page 305 *et seq.*). It gives the composition of the grain-ash of wheat, grown on the same land, in four characteristic seasons—1852, 1856, 1858, and 1863; the land being treated with farmyard manure:—

	HARVESTS			
	1852.	1856.	1858.	1863.
Weight per bushel of grain, lb.	58.2	58.6	62.6	63.1
	PERCENTAGE COMPOSITION OF ASH			
Iron Oxide, Fe_2O_3	0.95	0.86	0.90	0.43
Lime, CaO	2.79	2.53	2.61	2.34
Magnesia, MgO	12.77	11.71	11.17	11.41
Potash, K_2O	27.22	29.27	31.87	31.54
Soda, Na_2O	0.45	0.42	0.28	0.66
Phosphoric Anhydride, P_2O_5	54.69	54.18	51.88	52.04
Sulphuric Anhydride, SO_3	0.14	0.23	0.75	0.93
Chlorine, Cl_2	trace	0.07	0.06	trace
Silica, SiO_2	0.99	0.75	0.49	0.65
Total	100.00	100.02	100.01	100.00

The ash constitutes about 1.5 per cent. of wheat, and about 0.4 per cent. of the finished flour, while bran yields from 5 to 7 per cent. of ash. It will be noticed that more than half the wheat ash consists of anhydrous phosphoric acid; this is principally in combination with potash, forming potassium phosphate. The magnesia is also present as a salt of phosphoric acid. The greater part of wheat ash, therefore, consists of potassium phosphate, and is soluble in water.

148. Composition of the Ash of a Wheat and its Mill Products, Teller.—The following series of ash analyses was made for the purpose of obtaining some further information concerning the distribution of various ash ingredients in the wheat grain and in the different products of modern flouring mills. The figures given in the table indicate in per cent. of total ash, the amount of each constituent named.

Constituents.	Patent Flour.	Straight Flour.	Low Grade.	Dust Room.	Ship Stuff.	Bran.	Wheat.
Silica	2.33	1.28	0.50	1.34	0.49	0.97	1.04
Alumina	0.41	0.15	0.12	0.04	0.18	0.07	0.11
Ferric Oxide	0.47	0.26	0.25	0.30	0.37	0.27	0.27
Potash	38.50	36.31	32.27	30.85	28.03	28.19	29.70
Soda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lime	5.59	5.65	4.51	3.53	2.80	2.50	3.10
Magnesia	4.39	6.44	9.33	12.90	13.27	14.76	13.23
Phosphoric Acid	48.05	49.32	53.10	49.94	54.62	52.81	52.14
Sulphur Trioxide	0.16	0.52	0.00	0.58	0.00	0.10	0.22
Chlorine	—	—	—	—	—	0.01	0.01
Zinc Oxide	—	0.04	—	0.46	0.36	0.27	0.24
Total	99.90	99.97	100.08	99.94	100.12	99.95	100.06
Per cent. total ash in each	0.31	0.40	0.70	2.50	3.08	5.25	1.62

Among the variations in composition in the ash from different parts of the wheat grain, the most noticeable are the very marked increase in the proportion of potash and lime toward the interior of the grain, and the still greater decrease in the proportion of magnesia in the same direction, that is, from the bran to the whitest flour. (*Bulletin, Arkansas Agric. Expt. Station,* 1896.)

149. Organic Constituents: Fatty Matters.—Of the numerous organic bodies found in wheat, fat has not been chosen as the first to be described because of its importance as a grain constituent, but because it has the simplest composition of the organic bodies present, and therefore may fitly serve as an introduction to the chemistry of the more complicated compounds to follow. All grains contain more or less fat; rice has the least quantity, viz. 0.1 per cent.; maize and oats have respectively 4.7 and 4.6 per cent.; wheat occupies a medium position with a percentage of 1.2 to 1.5. The fat of wheat is not equally disseminated through the grain, but is almost entirely contained in the germ and husk or bran. An analysis by Church gives the quantity of fat in "fine wheat flour" as 0.8; it is, however, doubtful if this analysis were made since the time when the problem of degerming flour has received so much attention from the miller.

It has been already explained that the fats are salts of certain acids, with glycerin as a base. They are characterised by their unctuous nature, and by leaving a greasy stain on paper or linen. Fats are insoluble in water, and from their low specific gravity float on the surface of that liquid. On the other hand, all fatty bodies dissolve readily in either ether or light petroleum spirit. As food stuffs, the fats occupy a high position; in tables giving the relative nutritive value of different articles of food, fat heads the list. If this were the only point to be considered, the presence of fats in wheat and flour would be highly advantageous. They have, unfortunately, one great drawback, and that is that they become rancid on standing. This effect is particularly noticeable in flour imperfectly freed from germ. The rancidity is due to slow oxidation of certain constituents of the fat; this change may proceed sufficiently far to seriously affect the flavour of the flour, without the fat as a whole being very greatly changed. The fat of wheat is of a light yellow tint, melts at a low temperature, and gradually darkens in colour on being kept. This change proceeds rapidly in the fat when maintained at a temperature of 70 or 80° C.

König states that the fat of rye, a grain very similar to wheat, has the following composition:—

Glycerin	1.30	per cent.
Oleic acid	90.60	”
Palmitic and stearic acids	8.10	”

According to König, therefore, the fat of rye consists largely of free fatty acids, the glycerin present being insufficient to neutralise but a small proportion of the acids present.

Stellwaag states that the fat of barley as extracted by ether has the following composition:—

Free fatty acids	13.62	per cent.
Neutral fats	77.78	”
Lecithin	4.24	”
Cholesterin	6.08	”

An examination of wheat fat in the authors' laboratory gave the following results: A sample of perfectly fresh wheat germs was obtained from the miller and extracted repeatedly with light petroleum spirit in the cold. The extract was filtered, the spirit distilled off, and the residue heated very gently until completely free from the odour of petroleum. A light yellow oil, which in twenty-four hours deposited a trace of crystalline fat, was the result. The following analytic data were obtained on the thoroughly mixed oil and fat:—

Free fatty acids	5.92	per cent.
Neutral fats	94.08	„
	100.00	

More detailed analysis gave the following results:—

Lower fatty acids (reckoned as butyric)	0.11	per cent.
Higher fatty acids (palmitic, stearic, etc.)	20.72	„
Oleic acid	52.24	„

The fat completely saponified very readily.

Spaeth (p. 233, *Analyst,* 1896) gives the following analytic data as to the properties of wheat fat:—

Specific Gravity at 100° C. (water at 15°=1)	0.9068
Melting Point of Fatty Acids	34°
Saponification Value	166.5
Iodine Value	101.5
Reichert Meissl Value	2.8
Refractive Index at 25° C.	1.4851
„ „ on Zeiss's Refractometer Scale	92.0

150. Wheat Oil: de Negri, and Frankforter and Harding.—A somewhat exhaustive examination of the oil of wheat has been made by de Negri, who found the separated germs of wheat to contain 12.5 per cent. of fatty matter, of which 8 per cent. could be extracted by petroleum spirit. On removal of the solvent by distillation in a vacuum, there remained a clear yellow-brown mobile oil having a peculiar smell resembling that of wheat. This oil solidifies at 15° C. It is soluble in ether, petroleum ether, chloroform, and carbon disulphide; but is insoluble in cold absolute alcohol, though soluble, however, in thirty parts of hot alcohol. Glacial acetic acid dissolves at 65° C. an equal volume of oil. It is only slowly saponified by alcoholic potash.

Colour reactions: Haydenreich's reaction, orange-yellow with violet spots. Brullé's reaction, red tinge becoming blood red. Schneider's and also Baudoin's reaction gave no colour. Becchi's as well as Milliau's reaction gave a pale brown colour. The oil easily turns rancid. After standing a year a sample contained 43.86 per cent. of free acid calculated as oleic acid. Germs of different origin were found to give oils with varying constants.

Frankforter and Harding state that the oil extracted from the germ by ether has a golden yellow colour, and a characteristic odour of freshly ground wheat. Warmed to 100° C., the oil becomes reddish brown. It is a non-drying and not readily oxidisable oil. The following are the more important constants and particulars of composition as determined by de Negri, and Frankforter and Harding, respectively:—

Data.	De Negri.	Frankforter and Harding.
Specific Gravity at 0° C.	—	0.9374
” ” 15° C.	0.9245	0.9292
Solidification Point	15° C.	—
Melting Point of Fatty Acids	39.5° C.	—
Solidification Point of Fatty Acids	29.7° C.	—
Saponification Value	182.81	188.83
Iodine Value of Oil	115.17	115.64
” ” Fatty Acids	123.27	—
Refractometer Value (Zeiss-Wollny)	74.5	—
Free Acid calculated as Oleic Acid	5.65	4.07* 20.46
Glycerol (glycerin)	—	7.37
Lecithin	—	1.99
Paracholesterol	—	2.47

The figure marked by an asterisk is the amount per cent. of potassium hydroxide, KHO, required to neutralise the free acid. This figure × 5.027 = the acidity calculated as oleic acid. It will be seen that this sample is about four times as acid as that of de Negri. But like other oils, the acidity varies considerably with age and other conditions. (*de Negri, Chem. Zeit.*, 1898, **22**, 976, *and Frankforter and Harding, Jour. Amer. Chem. Soc.*, 1899, **758.**)

It is unusual to find germ oil with any brown tint as described by de Negri; pure germ is very pale yellow in colour and so also is the oil extracted therefrom. Possibly the germ on which de Negri worked contained a slight amount of bran from which the oil derived its colour.

Further explanation of the various analytic data will be given when dealing more fully with fats in the confectionery section of this work, Chapter XXVIII.

Experimental Work.

151. The student who proposes to master for himself the contents of this work, should endeavor to verify as many as possible of the various statements and descriptions by direct experiment. The following outline of experimental work is intended as a laboratory course of study on the subject.

152. Mineral Constituents.—Take a small quantity of whole wheaten meal, heat it to redness over a bunsen in a shallow platinum capsule or basin. At first the volatile constituents of the grain burn with flame, leaving a black mass of carbon and ash. Continue the application of heat until the carbon entirely burns away, leaving behind a greyish white ash. To this, when cool, add water; notice that most of it dissolves; add a few drops of hydrochloric acid, filter the solution, and make a qualitative analysis of it; test specially for calcium, magnesium, potassium, and phosphoric acid. It is well to test direct for these two latter constituents in separate small portions of ash. To test for potassium, dissolve up a portion in hydrochloric acid, filter and add a few drops of platinum chloride to some of the solution in a watch-glass; the presence of potassium is demonstrated by the formation of the yellow precipitate of the double chloride of platinum and potassium. Dissolve another portion of the ash in nitric acid, filter and add nitric acid and ammonium molybdate solution; after standing for some time in a warm place, phosphoric acid throws down a canary-yellow precipitate.

153. Fat.—In a tightly corked or stoppered bottle, shake up together some wheat meal and ether (or light petroleum spirit), allow the mixture to stand for an hour, giving it an occasional shake meanwhile. At the end of that time filter the solution through a paper into a clean evaporating basin and allow it to spontaneously evaporate. Notice that it leaves a small quantity of fat in the basin. Remember that the greatest care must be taken in all experiments with ether to avoid its taking fire. It is best to make this experiment in a room where there are no lights.

CHAPTER VI.

THE CARBOHYDRATES.

154. Definition of "Carbohydrates."—This name has been applied to a class of bodies composed of carbon, hydrogen, and oxygen, in which the latter two elements are present in the same proportion as in water, namely, two atoms of hydrogen for every one of oxygen. Thus, for example, starch contains to the six atoms of carbon, ten atoms of hydrogen to five atoms of oxygen. The carbohydrates comprise, among their number, bodies differing considerably in physical appearance and character, but yet exhibiting signs of close chemical relationship. Subjoined is a table of the more important carbohydrates, arranged into three groups, according to their empirical or simplest possible formulæ:—

Classification of Carbohydrates.

1. Glucoses, Hexoses ($C_6H_{12}O_6$).	2. Sucroses or Saccharoses, Di-hexoses ($C_{12}H_{22}O_{11}$).	3. Amyloses, Poly-hexoses *n* ($C_6H_{10}O_5$).
+Dextrose	+Cane Sugar	+Starch
—Lævulose	+Lactose	+Dextrin
+Galactose	+Maltose	Cellulose
		Gums

155. Constitution of Carbohydrates.—Some reference has already been made to the glucoses in the chapter on organic compounds. It is there shown that closely allied to the aldehydes is a family of compounds known as aldoses. Of these, the formula of hexose, one form of which is glucose, has been given and explained. In both aldehydes and aldoses, there occurs the carbonyl (CO) group in which the oxygen is directly united to the carbon by its two links or bonds. It will be noticed that this group is attached to the free end of the open chain of carbon atoms. Glucose has been regarded as an aldehyde of mannitol, and may be formed by processes of moderate oxidation from that alcohol:—

$$\left\{\begin{array}{l} CH_2HO \\ CHHO \\ CHHO \\ CHHO \\ CHHO \\ CH_2HO \end{array}\right. \text{or } C_6H_8(HO)_6 + O = \left\{\begin{array}{l} CH_2HO \\ CHHO \\ CHHO \\ CHHO \\ CHHO \\ COH \end{array}\right. \text{or } C_6H_{12}O_6 + H_2O.$$

Mannitol. Oxygen. Glucose. Water.

Conversely upon reduction, glucose takes up two atoms of hydrogen and is converted into mannitol. The formula given shows the composition and relationship of glucose, which name is now more specifically applied to dextrose. Lævulose, called also fructose, has the same simplest formula as dextrose, $C_6H_{12}O_6$, and like it contains the radical carbonyl. There is, however, this difference, the carbonyl is attached not to one of the free atoms of the carbon chain, but to the last but one, thus showing lævulose to be a ketose and closely allied to butyl-methyl ketone.

The sucroses may be regarded as bodies formed by the union of two molecules of the glucose type, with the elimination of a molecule of water, a reaction, however, which does not occur anything like so readily as the decomposition of a sucrose into its component molecules of glucose. Thus under the influence of weak acids cane sugar splits up into glucose and fructose:—

$$\underset{\text{Cane sugar.}}{C_{12}H_{22}O_{11}}+H_2O=\underset{\text{Glucose, Dextrose.}}{CH_2HO.(CHHO)_4.COH}+$$
$$\underset{\text{Fructose, Lævulose.}}{CH_2HO.(CHHO)_3.CO.CH_2HO.}$$

The structural composition of cane sugar is not indicated in the above equation, but the formulæ of the resultant products show them to be respectively an aldose and a ketose. Owing to their composition, the sucroses are regarded as di-hexoses.

The amyloses are much more complex bodies than are the preceding groups. They depart still further from the simplest hexose type, inasmuch as another molecule of water has been eliminated. This is clearly shown in the following specially written formulæ:—

$$\underset{\text{Two Molecules of Glucose.}}{C_{12}H_{24}O_{12}.}\qquad \underset{\text{One Molecule of Sucrose.}}{C_{12}H_{22}O_{11}.}\qquad \underset{\text{Two ``Units'' of Amylose.}}{C_{12}H_{20}O_{10}.}$$

The molecules of the amyloses are high multiples of the unit group, $C_6H_{10}O_5$. From their complexity they are termed poly-hexoses.

Brown and Morris in 1888 and 1889 contributed to the Chemical Society's Journal important papers on the Molecular Weights of the Carbohydrates. Their researches were based on Raoult's investigations on the lowering of the freezing point of a solvent by the solution in it of any substance. (Thus, salt water freezes at a lower temperature than pure water.) Raoult found that equivalent molecular proportions of different compounds cause under the same conditions a similar depression of the freezing point of the solvent. This offers a valuable means of determining molecular weight, as, knowing that of one body dissolved, that of others may be determined. Brown and Morris applied this method to the investigation of the carbohydrates.

MOLECULAR CONSTITUTION OF CARBOHYDRATES.

Substance.	Formula of Molecule.	Molecular Weight.
Dextrose ..	$C_6H_{12}O_6$	180
Cane Sugar	$C_{12}H_{22}O_{11}$	342
Cane Sugar, *same solution after inversion**	$C_6H_{12}O_6$	180
Maltose	$C_{12}H_{22}O_{11}$	342
Lactose, Milk Sugar	$C_{12}H_{22}O_{11}$	342
Arabinose	$C_5H_{10}O_5$	150
Raffinose	$C_{18}H_{32}O_{16}, 5H_2O$	594
Mannite or Mannitol	$C_6H_8(HO)_6$	182
Galactose†	$C_6H_{12}O_6$	180
Maltodextrin	$\left\{\begin{matrix}C_{12}H_{22}O_{11}\\(C_{12}H_{20}O_{10})_2\end{matrix}\right\}$	990
Amylodextrin	$\left\{\begin{matrix}C_{12}H_{22}O_{11}\\(C_{12}H_{20}O_{10})_6\end{matrix}\right\}$	2,286
Lowest or Stable Dextrin‡	$20C_{12}H_{20}O_{10}$	6,480
Soluble Starch	$5(C_{12}H_{20}O_{10})_{20}$	32,400

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* Cane Sugar after inversion is split up into dextrose and lævulose, and dextrose having a molecular weight of 180, so must lævulose, and be represented by the formula $C_6H_{12}O_6$.

† Galactose is the "dextrose" of lactose.

‡ The molecular weight, not only of the lowest or stable dextrin, is represented by the formula $(C_{12}H_{20}O_{10})_{20}$, but so also are those of the so-called higher dextrins, of which Brown and Morris examined a series. They find that "the numbers obtained with dextrins occupying very different positions in the series are strikingly identical."

The above table contains the results of their determinations, which molecular weights, with the exception of that of starch, were obtained by direct estimations. In this latter case the direct method was inapplicable, and, accordingly, recourse was had to an indirect method, based on the generally accepted hypothesis that the starch molecule must be at least five times the size of the dextrin molecule produced under certain conditions. Mannitol, having such an intimate relationship in constitution to the carbohydrates, is also included in the table.

It will be seen that, commencing with those most simple in constitution, the glucoses come first, and the amyloses last in order. In nature also no doubt the simpler bodies are first produced, and from these those which are more complex. In flour as a product of the finished and ripened grain, by far the greater part of the carbohydrates present is in the form of starch, and the chemistry of these bodies, in so far as bread-making is concerned, deals with the degradation or breaking down of the starch molecule into simpler substances, rather than with its building up. For this reason it will be preferable to begin our study of the carbohydrates with the amyloses, and then proceed to the other members of the family.

CELLULOSE, $nC_6H_{10}O_5$.

156. Occurrence and Physical Properties.—This body, of which there are numerous physical modifications, constitutes the framework or skeleton of vegetable organisms, in which it acts as a sort of connective tissue, binding and holding together the various parts and organs of plants. Woody fibre consists largely of cellulose and one or two closely allied substances, among which is lignin, a harder and more resistant body than cellulose, but of somewhat similar composition.

The pith of certain plants is nearly pure cellulose. Manufactured vegetable fabrics, as cotton and linen goods, and likewise unsized paper, are also cellulose in an almost pure form. Chemically pure Swedish filters consist of cellulose with only the most minute traces of other bodies. The horny part of certain seeds, such as "vegetable ivory," consist of a form of cellulose, which is of interest as being a "reserve" store of nutriment, as starch is in wheat and other seeds.

Pure cellulose is white, translucent, of specific gravity of about 1.5, and is insoluble in water, alcohol, ether, and both fixed and volatile oils. An ammoniacal solution of copper hydroxide dissolves cellulose completely; this reagent may be prepared by precipitating copper hydroxide from the sulphate, by sodium hydroxide, and then dissolving the thoroughly washed precipitate in strong ammonia. This solution dissolves cotton wool, or thin filtering paper, forming a sirupy solution; on the addition of slight excess of hydrochloric acid, the cellulose is precipitated in flaky masses; these, on being washed and dried, produce a brittle horny mass. This re-precipitated cellulose is not coloured blue by iodine, and still presents the same chemical properties as ordinary cellulose.

157. Behaviour with Chemical Reagents.—Cellulose, on being boiled with water under pressure, is converted into a body bearing some resemblance to dissolved starch, inasmuch as it is coloured blue by iodine. The same effect is produced more rapidly by treatment with acids. Boiling with dilute sulphuric or nitric acid, or strong hydrochloric acid, breaks up cellulose into a flocculent mass, but without any change in composition. Treatment with stronger nitric acid changes cellulose into nitro-substitution products called gun cottons or pyroxylin; while that acid, in a yet more concentrated form, oxidises cellulose to oxalic acid. By the action of strong sulphuric acid, cellulose is converted into a form of sugar known as cellobiose, $C_{12}H_{22}O_{11}$. Concentrated solutions of potash or soda also dissolve cellulose, with the formation apparently of the same compound. Sulphuric acid, diluted with about half or quarter its bulk of water, has a most remarkable action on unsized paper. The paper on being dipped in the acid for a few seconds, and then washed with weak ammonia, is found to be changed into a tough, parchment-like material, which may be used for many of the purposes to which animal parchment is applied. This body is familiar to confectioners, as being sold under the name of parchment paper for tying down pots containing jam and other substances. Filter papers, on being momentarily immersed in nitric acid of density 1.42, are remarkably toughened, the product being still pervious to liquids and therefore suitable for filtering purposes. Such papers are recommended for filtering bodies that have to be removed from the paper while wet, and are now sold commercially for that purpose.

158. Existence in Wheat.—There are three forms of cellulose present in wheat, of which the following is a brief description:—

1. The lignified or woody cellulose of the bran, which is entirely removed in the process of making white flour. In whole-meal, which contains the bran, the lignified cellulose undergoes no change in the operations of bread-making, nor afterwards during the processes of human digestion.

2. The parenchymatous cellulose, which forms the cell-walls of the endosperm. This disappears during germination of the grain, and is far more easily dissolved by all reagents than is lignin or woody cellulose.

3. So-called starch cellulose constitutes the envelopes or cellulose-skeleton of the starch cells. It is this form which is most readily converted into the starch-like body, giving a blue colouration with iodine.

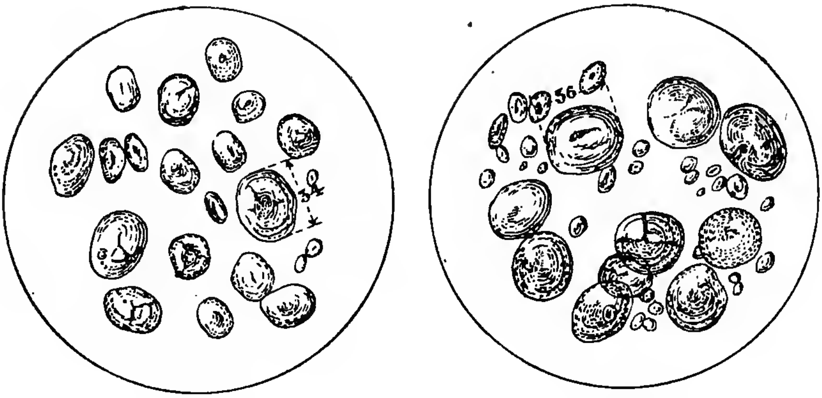
159. Composition.—The formula, $C_6H_{10}O_5$, is the simplest that can be derived from the percentage composition of cellulose, but there is little doubt that the molecule really consists of a number of groups of $C_6H_{10}O_5$ united together, and is at least as complex as that of starch.

$$\text{STARCH,}\begin{cases}(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\end{cases}$$

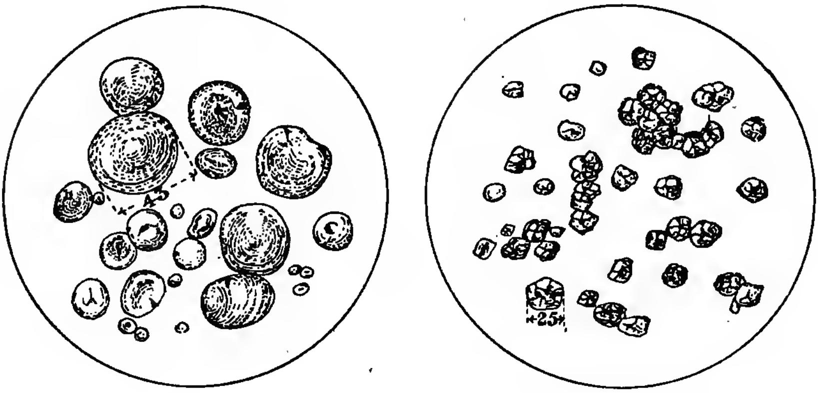
160. Occurrence.—The starchy matters of wheat are of vast importance as constituting the greatest portion of the whole seed. Starch is not only found in wheat, but also in other seeds; and in fact in most vegetable substances used as food. From whatever source obtained, starch has the same chemical composition, but varies somewhat in physical character.

161. Physical Character.—Starch, when pure, is a glistening, white, inodorous granular powder. If a pinch be taken and squeezed between the thumb and finger, a peculiar "crunching" (crepitating) sound is heard. Starch has a specific gravity of from 1.55 to 1.60. Starch is extremely hygroscopic, absorbing moisture with avidity; in the form in which it is usually sold it contains about 18 per cent. of water. Wheat starch after drying in a vacuum still retains about 11 per cent. of water. Heating in a current of dry air to a temperature of 110° C. renders it practically anhydrous.

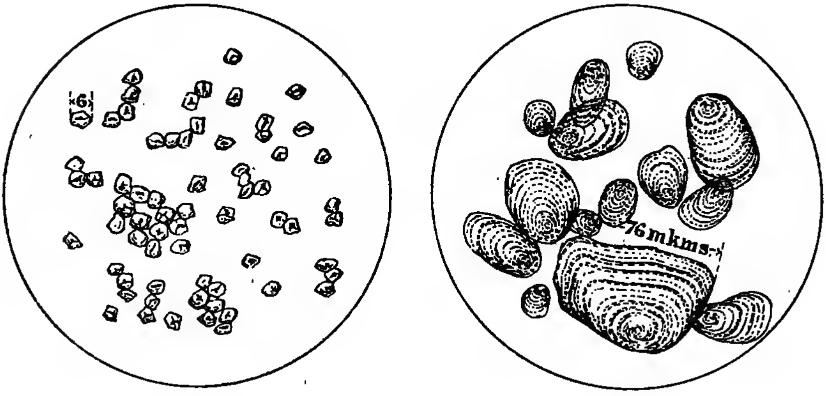
PLATE I.



Barley. *Wheat.*



Rye. *Maize.*



Rice. *Potato.*

MICROSCOPIC SKETCHES OF VARIOUS STARCHES.

Magnified about 100 diameters.

B.E. Fuller

162. Microscopic Appearance.—The microscope shows starch to be composed of minute grains, each having a well defined structure. These grains are respectively termed starch cells, granules, or corpuscles. Careful examination reveals that each cell consists of an outer coating or pellicle formed of a very delicate type of cellulose, to which the name "starch cellulose" is applied. This envelope is built up of several layers, arranged concentrically one over the other, and contains within its interior a substance which may be called starch proper, in distinction from the enclosing matter. This starch proper is also termed "starch granulose" or "amylose." On careful examination these separate coats appear as a series of more or less concentric rings, having for a nucleus a dark spot or cross, termed the "hilum." The actual size and shape of starch cells vary with the source from which the starch is derived; thus the grains of starch from potatoes are comparatively large, while those of rice are extremely minute. When examined by polarised light certain starches exhibit characteristic appearances—these are referred to in detail in the table following. A description of the phenomena of polarisation is given in Chapter IV. It is possible in many instances to determine the origin of a sample of starch by its microscopic characteristics; it follows that impurities may similarly be detected; also, as all vegetable adulterants of flour contain starch, admixture of other grains, as maize, rice, etc., is in this manner revealed.

In Plate I is given the appearance of the more important starches as seen under the microscope.

MICROSCOPIC CHARACTERS OF VARIOUS STARCHES.

163. Wheat.—Wheat starch is extremely variable in size, the diameter of the corpuscles being from 0.0022 to 0.052 m.m. (0.00009 to 0.0029 inch). Many observers point out that medium sized granules are comparatively absent. The grains are circular, or nearly so, being at times somewhat flattened. The concentric rings are only seen with difficulty; the hilum is not so visible as in certain other starches. Polarised light shows a faint cross. In old samples of wheat or flour the granules show cracks and fissures: this applies more or less to all starches.

164. Barley.—Granules more uniform in size than those of wheat, also somewhat smaller; average diameter 0.0185 m.m. (0.00073 inch); a few exceptionally large granules may be found measuring as much as 0.07 m.m. Shape, slightly angular circles. Concentric rings and hilum either invisible or only seen with difficulty.

165. Rye.—Diameter of granules from 0.0022 to 0.0375 m.m. (0.00009 to 0.00148 inch). Taking a whole field, the average size of granules is usually somewhat higher than those of wheat. Shape, granules are almost perfectly round, here and there show cracks. Concentric rings and hilum only seen with difficulty.

166. Oats.—Diameter of granules, 0.0044 to 0.03 m.m. (0.00017 to 0.00118 inch). Granules are angular in outline, varying from three to six-sided.

167. Maize.—Diameter of granules, average size, 0.0188 m.m. (0.00074 inch). Shape, from round to polyhedral, mostly elongated hexagons, with angles more or less rounded. Concentric rings scarcely visible, hilum star-shaped.

168. Rice.—Diameter of granules from 0.0050 to 0.0076 m.m. (0.0002 to 0.0003 inch). Granules are polygonal in shape, mostly either five or six-sided, but occasionally three-sided. Are usually seen in clusters of several joined together. A very high magnifying power shows a starred hilum.

169. Potatoes.—Diameter of granules from 0.06 to 0.10 m.m. (0.0024 to 0.0039 inch). The granules vary greatly in shape and size; the smaller ones are frequently circular; the larger grains are mussel or oyster shaped. The hilum is annular, and the concentric rings incomplete, but, especially in the larger granules, clear and distinct. The rings are distributed round the hilum in very much the same way as the markings show on the outside of a mussel shell. With polarised light a very distinct dark cross is seen, the centre of which passes through the hilum.

170. Canna Arrowroot, or Tous les mois.—Diameter of granules varies from 0.0469 to 0.132 m.m. (0.0018 to 0.0052 inch). The shapes differ considerably, from round to more or less elongated ovals. The hilum is eccentric; the rings are incomplete, extremely fine, narrow and regular. Under polarised light a more distinct cross is seen than with the potatoes.

171. Preparation and Manufacture of Starch.—For experimental purposes, starch can readily be obtained from wheaten flour by first preparing a small quantity of dough; this is then wrapped up in a piece of fine muslin, or bolting silk, and kneaded between the fingers in a basin of water. The milky fluid thus produced deposits a white layer of starch on the bottom of the vessel, which may be carefully air-dried. The starch of barley and the other cereals may be obtained in a sufficiently pure form for microscopic study in the same manner. Potatoes require to be first scraped, or rubbed through a grater, into a pulp; this pulp must then be enclosed in the muslin and the starch washed out.

On the manufacturing scale, starch is obtained from wheat and other grains by first coarsely grinding and then moistening the meal with water. This is allowed to stand, and after three or four days fermentation sets in, more water is then added, and the putrefactive fermentation allowed to proceed for some three or four weeks. By the end of this time the gluten and other nitrogenous matters are dissolved. They are then readily separated from the starch by washing, after which the starch is dried. Starch is now largely manufactured from rice by a process in which the grain is subjected to the action of very dilute caustic soda, containing about 0.3 per cent. of the alkali; this reagent dissolves the nitrogenous bodies and leaves the starch unaltered. The so-called "corn flour" is the starch of maize prepared after the same fashion. Potato starch is obtained by first rasping the washed potatoes into a pulp by machinery; the pulp is next washed in a sieve, the starch is carried through by the water, and after being allowed to subside is dried on a tile floor at a gentle heat.

172. Gelatinisation of Starch.—Starch is insoluble in cold water, and cannot be dissolved by any known liquid without change; this follows from its having a definite organic structure; when this is destroyed, as must of necessity be the case whenever a solid is rendered liquid, it cannot by any artificial means be again built up in the same form.

As previously stated, the starch granules consist of an outer envelope of cellulose, enclosing what is termed "amylose," or starch proper. This latter body is soluble, and although pure starch in the granular form yields no soluble substance to water, yet if the cellulose envelopes be ruptured by mechanical means, it is then found that on treatment with water at ordinary temperatures a soluble extract is obtained. When, however, starch is subjected to the action of boiling water a marked change ensues:

under the influence of heat the little particles in the interior, by swelling, burst the containing envelope, and dissolving in the water form a thick and viscous liquid, which on cooling, if sufficiently concentrated, solidifies into a gelatinous mass. This solution of starch is somewhat cloudy, owing to the undissolved particles of starch cellulose remaining in suspension. These may be, in great part, removed by filtration.

This bursting of the starch granules is frequently spoken of as the "gelatinisation" of starch, and the resulting substance as "starch-paste." The temperature at which this change occurs varies with the nature and origin of the starch.

The following table gives particulars as to the gelatinising temperatures of starch from different sources. The figures to the left are those of Lippman, while to the right are given the results of a series of later determinations made by Lintner, and published in 1889. It may be taken that Lintner's temperatures are for complete gelatinisation.

TEMPERATURE OF GELATINISATION OF STARCH.

	Granules Swollen.		Gelatinisation Commenced.		Gelatinisation Completed.		Complete Gelatinisation, Lintner.	
Source of Starch.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.
Barley	37.5	99.5	57.2	135	62.2	144	80	176
Maize	50.0	122.0	55.0	131	62.2	144	75	167
Rye	45.0	113.0	50.0	122	55.0	131	80	176
Potato	46.1	115.0	58.3	137	62.2	144	65	149
Rice	53.8	129.0	58.3	137	62.2	144	80	176
Wheat	50.0	122.0	65.0	149	67.2	153	80	176
Green Malt	—	—	—	—	—	—	85	185
Kilned Malt	—	—	—	—	—	—	80	176
Oats	—	—	—	—	—	—	85	185

These temperatures of gelatinisation assume that the walls of the starch-containing cells have been broken down, and that excess of water is present; otherwise the temperature of gelatinisation is considerably higher: thus, in stiff biscuit doughs, and even in bread, much of the starch remains ungelatinised even after being baked.

There is doubt as to whether or not gelatinised starch is in a state of true solution. When filtered, the clear filtrate gives a blue colouration with iodine (a characteristic reaction of starch), but on dialysis through an animal or vegetable membrane, or even filtration through porous earthenware, the starch is removed. This has led to the view that the starch in starch paste is simply in a state of extremely fine division, but more probably the state is one of true solution, and the removal by filtration is due to the highly colloid nature of starch.

173. Soluble Starch.—On treating starch with dilute acids in the cold, the starch loses its power of gelatinisation, and becomes what is known as "soluble starch." In this form no change of appearance is observed in the granules, but the starch readily dissolves in hot water to a clear limpid liquid. Lintner directs soluble starch to be prepared in the following manner: Pure potato starch of commerce is taken and mixed with a sufficient quantity of 7.5 per cent. hydrochloric acid to cover it, and allowed to stand either at ordinary temperatures for seven days, or for three days at 40° C. By that time the starch will have lost the power of gelatinisation, and is repeatedly washed with cold water until every trace of acid is removed. It is then air-dried, and is readily and completely soluble in hot water to a bright and limpid solution.

Soluble starch is probably a polymeride of ordinary starch, and when dissolved, then known as "starch solution," closely resembles "starch-paste" in its chemical behaviour.

174. Action of Caustic Alkalies on Starch.—Treatment with cold dilute solutions of potash or soda causes starch granules to swell enormously; the volume of starch grains may thus be made to increase 125-fold. This reaction also serves for the differentiation of the various starches. H. Symons recommends the use of soda solutions of different strengths: a small quantity of the starch is shaken up in a test-tube for ten minutes with one of the soda solutions, and then a drop of the liquid is examined under the microscope. The following is a table of results thus obtained:—

	A few Starch granules dissolved in a solution of	The greater number dissolved in a solution of	All dissolved in a solution of
Potato	0.6 per cent.	0.7 per cent.	0.8 per cent.
Oats	0.6 ,,	0.8 ,,	1.0 ,,
Wheat	0.7 ,,	0.9 ,,	1.0 ,,
Maize	0.8 ,,	1.0 ,,	1.1 ,,
Rice	1.0 ,,	1.1 ,,	1.3 ,,

175. Action of Zinc Chloride.—Treatment with zinc chloride also causes a remarkable swelling of the granules of starch; this reaction, when viewed under the microscope, serves admirably to show the structure of the corpuscles. Some concentrated solution of zinc chloride is tinged with a trace of free iodine. A few grains of the starch are placed on a glass slide, together with a small drop of this solution. No change is observed until a little water is also added. They then assume a deep blue tint, caused by the iodine, as explained in a subsequent paragraph, and gradually expand. A frill-like margin developes round the granule, the foldings of this frill open out in their turn, until the granules at last swell up to some twenty or thirty times the original volume, and then appear as limp-looking sacs. These changes, so far as can be seen, are not accompanied by any expulsion of the inner contents of the cell.

176. Properties of Starch in Solution.—A solution of starch is colourless, odourless, tasteless, and perfectly neutral to litmus. Starch is a highly colloid body, and can be readily separated by dialysis from crystalline substances. On evaporating a solution of starch, it does not recover its original insolubility. Starch solution causes right-handed rotation of polarised light. Starch amylose is insoluble in alcohol, and may be entirely precipitated from its aqueous solution by the addition of alcohol in sufficient quantity. Tannin precipitates both starch-paste and soluble starch, the precipitate being re-dissolved on heating. Barium hydroxide gives an insoluble compound with solution of starch, and is used in this way in some processes of starch estimation.

Soluble starch, owing to the formation of a hydriodide of starch $(C_{24}H_{40}O_{20}I)_4HI$, is coloured an intense blue by the addition of iodine in extremely small quantities. This blue colouration disappears on heating the solution, but reappears on its being cooled. This reaction is exceedingly delicate, and is practically characteristic of starch. For the purpose of this test, the iodine may be dissolved in either alcohol or an aqueous solution of potassium iodide; for most purposes preferably the latter. For the occurrence of this reaction, the presence of water is apparently essential; for if wheaten flour be moistened with an alcoholic solution of iodine no colouration is produced other than the natural brownish yellow tint of tincture of iodine. But with a potassium iodide solution the flour assumes a blue colour so intense as to be almost black.

The iodine colouration of starch is only caused by free iodine, not by iodine compounds; and is not produced except in the presence of hydriodic acid or an iodide. Potash or soda in solution, when added to dissolved iodine, immediately combine therewith to form iodides and iodates; consequently, the iodine test for starch is inapplicable in an alkaline medium. In case a solution to be tested for starch is alkaline to litmus, cautiously add dilute sulphuric acid, until neutral or very slightly acid; the test for starch may then be made. The only compounds usually likely to interfere with the iodine reaction for starch are some of the dextrins; these bodies combine with iodine, forming either colourless or brown compounds; but unless present in large quantities do not prevent the detection of starch. Iodine combines with starch more readily than with dextrin, consequently the iodine should in such cases be added in very small quantities at a time, when the blue colouration due to the starch will appear before the brown tint produced by dextrin. In testing for starch the addition of iodine solution should be continued until an excess of iodine is present in the solution.

In bodies such as starchless biscuits, of which washed gluten may form a constituent, it is sometimes found, on dropping a solution of iodine on the broken surface of the biscuit, that a blue colouration is produced, but that prolonged boiling fails to yield a solution which gives an iodine colouration. The probable explanation seems to be that under the influence of heat traces of starch cellulose in the biscuit products are converted into the soluble variety, and hence give a colouration *in situ,* but are in such small quantity and so firmly imprisoned within the cellulose as not to be liberated by boiling. It is not sufficient in making starch tests on solid substances to trust to adding iodine to the substance itself: the substance should also be extracted with boiling water, and the test made on the filtered solution.

Starch does not cause a precipitate with Fehling's solution, that is, it does not reduce an alkaline solution of copper sulphate in potassium sodium tartrate. See paragraph 183, on Reducing Power.

Starch under the influence of heat, and readily when treated with certain other bodies, is transformed into others of the carbohydrates.

DEXTRIN, $20C_{12}H_{20}O_{10}$, or $40C_6H_{10}O_5$, $+ H_2O = \left\{\begin{matrix}(C_6H_{10}O_5)_{39} \\ C_6H_{12}O_6.\end{matrix}\right.$

177. Occurrence.—Dextrin is principally known as a manufactured article, but also occurs in small quantities as a natural constituent of wheat and most bodies containing starch.

178. Physical Character.—In appearance, dextrin is a brittle transparent solid, very much resembling the natural gums, as gum arabic. It is colourless, tasteless, and odourless. Dextrin is a colloid body, and is very soluble in water, and it is also soluble in dilute alcohol; but it is insoluble in absolute or even concentrated alcohol, by means of which it may be precipitated from its solutions. Dextrin is also insoluble in ether. Surfaces moistened with a solution of dextrin, and then allowed to dry in contact with each other, adhere firmly. Commercial dextrin has usually a more or less brown tint from the presence of caramel in small quantity.

179. Preparation.—Dextrin is usually prepared by the action of heat, with or without certain reagents, on starch. The starch may be maintained at a temperature of about 150° C. until it assumes a brown colour: treatment with water then dissolves out dextrin in an impure form. If the starch be first moistened with water containing a minute quantity of nitric acid, the change proceeds much more rapidly; the starch should in this case be heated to about 200° C. The substance thus yielded is that known as British gum, and is largely used for sizing calicoes and other purposes in commerce. If starch solution be boiled with dilute sulphuric acid until it no longer gives a blue colouration with iodine, dextrin will be found in the solution, but mixed with maltose. Certain nitrogenous bodies also possess the power of converting starch into dextrin and maltose.

180. Chemical Character.—Dextrin was formerly supposed to consist of a mixture of polymeric bodies of closely similar chemical character. These several dextrins were separated into two groups by their difference in behaviour when treated with iodine solution. The members of one of these groups, known as "erythro-dextrins," were found to strike a reddish-brown colouration on treatment with iodine; while the others, which were classified as "achroo-dextrins," yielded no colouration when iodine was added. It has already been stated that Brown and Morris in 1889 investigated the molecular weights of the carbohydrates, and that they found the results given by the various dextrins were practically identical. The formerly held theory assumed that the erythro-dextrins contained in the molecule 8 and 9 respectively of the group $C_{12}H_{20}O_{10}$; while the molecular formula of the achroo-dextrins included from 2 to 7 of the $C_{12}H_{20}O_{10}$ group. In face of Raoult's method, giving identical molecular weights for the whole of the dextrins, the view of their being polymeric bodies is no longer tenable. The iodine colouration, produced by the so-called erythro-dextrins, is due to the presence of certain other bodies, termed "amyloïns," which will subsequently be described.

Dextrin has a powerful action on polarised light, twisting the ray to the right: its name is derived from this property. A solution of dextrin in some respects resembles one of starch; they are, however, distinguished by the dextrin giving no blue colour when treated with iodine. Dextrin was formerly supposed to exercise no reducing action on Fehling's solution, and that in that respect its behaviour was similar to that of starch. But more recent observers, among whom are Brown and Millar (*Jour. Chem. Soc.*, 1899), point out that dextrin has a reducing power of about R 5.8.

THE SUGARS—*Maltose, Cane Sugar, Milk Sugar, and Glucose.*

181. General Properties.—As already explained, the sugars are a subdivision of the class of bodies known as carbohydrates; they are characterised by having a more or less sweet taste, and are soluble in water. Many are natural products occurring both in the animal and vegetable kingdom.

182. Maltose, $C_{12}H_{22}O_{11}$.—This body occurs in company with dextrin in starch solutions which have been treated with dilute sulphuric acid until the solution no longer yields a blue colouration with iodine. It forms a most important constituent of malt extract, amounting to from 60 to 65 per cent. of the total solid matter. In the pure state, maltose consists of small hard crystalline masses or minute needles, which are soluble in water and dilute alcohol. Maltose, being a crystalline body, may be separated from dextrin by dialysis, and also by precipitating the dextrin by means of strong alcohol. A solution of maltose causes a right-handed rotation of a ray of polarised light. Maltose gives no colouration with iodine, but, in common with certain other of the sugars, exercises a reducing or deoxidising action on some metallic salts.

183. Reducing Power.—This reducing action is most commonly tested by means of the reagent known as "Fehling's solution," which consists of sulphate of copper, tartrate of potassium and sodium, and sodium hydroxide, dissolved in water. If sodium hydroxide be added to a solution of copper sulphate, a precipitate of copper oxide, CuO, combined with water, is thrown down; the sodium and potassium tartrate redissolves this and forms a deep blue solution, which may be boiled for some minutes without alteration. Now certain varieties of sugar reduce the CuO to Cu_2O; that is, they take away oxygen, the change being represented by $2CuO = Cu_2O + O$. The oxygen is taken by the sugar, and for our present purpose need not be traced further. The Cu_2O, or copper sub-oxide, thus formed is insoluble in the Fehling's solution, and hence is precipitated, first as a yellow and then as a brick-red powder. The cupric oxide reducing power, or, more shortly, the cupric reducing power of a substance, has been defined by O'Sullivan as "the amount of cupric oxide calculated as dextrose, which 100 parts reduce" from Fehling's solution under usual conditions of analysis. By careful experiment it has been found that—

100	grams of	dextrose	reduce	220.5	grams of CuO.
100	„	maltose	„	137.8	„ „

If in the case of maltose the reduced CuO be assumed to be caused by dextrose, and calculated as such, then—

$$\frac{137.8 \times 100}{220.5} = 62.5 = \text{cupric reducing power of maltose.}$$

Another way of expressing the same thing is—The cupric oxide reduced by a given weight of dextrose being 100, the amount reduced by the same weight of any other body is taken as the cupric oxide reducing power of that body.

For cupric reducing power the symbol K or κ is employed, that is to say, the amount of reducing sugars calculated as *dextrose* from the CuO or Cu_2O precipitate = K.

In the case of sugars resulting from changes produced in starch, the present more widely adopted rule is to take the reducing power of maltose as 100, and that of other bodies in terms of that of maltose. For the cupric reducing power thus expressed, the symbol R is employed. For example, if starch is converted into a mixture of bodies, one-fifth of which is maltose, and the remainder without reducing action, then the cupric reducing power of the mixture would be R 20.

184. Cane Sugar, $C_{12}H_{22}O_{11}$.—Cane sugar is widely spread in nature: it is found in certain roots, as beet-root, in the sap of trees, as the maple, and in the juice of the sugar cane. These natural solutions are first purified, and then the sugar obtained by crystallisation. The sugar found in perfectly sound wheat is either identical with, or closely allied to, cane sugar. Pure cane sugar is colourless, odourless, and soluble in water, to which it imparts a sweet taste. Boiling water dissolves sugar in all proportions, while cold water dissolves about three times its weight. Sugar is insoluble in ether, chloroform, and petroleum spirit; but is very slightly soluble in absolute alcohol, and sparingly soluble in rectified spirits of wine. The purest commercial form of sugar is that sold by the grocers as "coffee sugar," and consists of well defined crystals about three-sixteenths of an inch across. This, when dried at 100° C. to expel any water that may be present, is sufficiently pure for most experimental work with sugar. A solution of cane sugar exercises a right-handed rotation on a polarised ray of light. Cane sugar produces no colouration with iodine, neither does it cause any precipitate in Fehling's solution. By the action of heat, cane sugar melts, and if then allowed to cool, forms the solid termed "barley-sugar"; a prolongation of the heat results in giving the sugar a deeper colour. Many sweetmeats consist of sugar thus treated. The darkening in colour is due to the fact that at moderately high temperatures (210° C. = 410° F.) sugar begins to undergo decomposition. Watery vapour and traces of oily matter are evolved, leaving behind a substance soluble in water, to which it imparts a rich brown tint. The characteristic sweet taste of sugar has then disappeared, and the liquid is no longer capable of fermentation by yeast. The change has resulted in the formation of a brown substance, termed caramel, to which the formula $C_{12}H_{18}O_9$ has been given. Caramel is, however, rather a mixture of bodies than a definite chemical compound. The browning of dextrin and starch when heated is also due to the formation of caramel.

185. Milk Sugar or Lactose, $C_{12}H_{22}O_{11}$.—This sugar is principally of interest as being that present in milk, which contains quantities of it varying from 4 to 5 per cent.

It will be noticed that the three sugars—maltose, cane sugar, and milk sugar—have all the same formula.

186. The Glucoses or Hexoses, $C_6H_{12}O_6$.—Several modifications of glucose exist; of these, two only are of importance in connection with the present subject, viz., glucose, otherwise known as dextrose or dextro-glucose, and fructose, called also lævulose or lævo-glucose.

187. Glucose or Dextrose.—This form of sugar exists as a natural product in the juices of many fruits, notably the grape and sweet cherry. The former yields about 15 per cent. of grape sugar. Glucose also occurs in the flowers of certain plants, and is derived from these by bees in the shape of honey, of which the glucoses are the principal constituents. Glucose is also found in large quantity in the urine of diabetic patients; some doubt exists as to whether this sugar is absolutely identical with the glucose of fruits. Glucose, when pure, occurs in crystalline masses: it has a sweet taste; but, weight for weight, is said to possess much less sweetening action than does cane sugar. (But see Chap. XXVIII.) A solution of glucose exercises a right-handed rotation on a ray of polarised light, and from this property has received the name of dextrose. Among the sugars, glucose is specially noticeable for the great ease with which it undergoes alcoholic fermentation. Like maltose, glucose exercises a reducing action on Fehling's solution, producing a red precipitate of cuprous oxide.

188. Fructose or Lævulose.—This sugar occurs in company with glucose in certain fruits, and also in honey. Fructose crystallizes from an alcoholic solution in long crystals; it possesses greater sweetening power than glucose, and offers more resistance to alcoholic fermentation. A solution of lævo-glucose exercises a left-handed rotation on a ray of polarised light, thus distinguishing it from dextro-glucose; the two names are based on the respective right- and left-handed rotary power of these glucoses. Lævo- and dextro-glucose both reduce Fehling's solution, but the reducing power of fructose is rather the less of the two.

189. Commercial Glucose.—Glucose, in a more or less pure form, is largely manufactured for commercial purposes. Under the names of "saccharum," "invert sugar," etc., it is used as a substitute for malt by brewers and distillers. Various forms of confectionery and fruit jams contain glucose as an important constituent. Glucose occurs in two forms in commerce: the one is a thick and almost colourless syrup, the other is a hard crystalline body, varying in colour from almost white to pale brown. Glucose is usually made from starch by the action of heating with dilute sulphuric or oxalic acid. For the purpose, either maize or rice is usually selected. Invert sugar is produced from cane sugar by heating with dilute acid. The following are analyses of different types of commercial glucoses:—

I. Brewer's solid starch glucose (Morris).
II. Confectioner's sirupy glucose (The authors).
III. Brewer's invert sugar (Morris).

	I.	II.	III.
Glucose	57.16	7.50	66.92
Maltose	8.09	60.92	—
Sucrose	—	—	0.80
Dextrin	16.63	16.20	—
Proteins	0.97	—	0.59
Mineral matter	1.45	0.18	1.59
Water	15.70	15.20	22.21
	100.00	100.00	
Unfermentable matter, etc.	..	..	7.89
			100.00

The glucose in these commercial products is a mixture of dextrose and lævulose. The sirupy glucoses consist principally of maltose and dextrin. "Invert sugar" is so called because such sugar rotates the ray of polarised light to the left instead of to the right, as does normal cane sugar.

THE AMYLOINS—*Amylo-dextrin, Malto-dextrin.*

190. Constitution.—The term "amyloïns" was proposed by Armstrong as a convenient name for a group of bodies which are compounds of varying proportions of the amylin or dextrin group, $C_{12}H_{20}O_{10}$, with the amylon or maltose molecule, $C_{12}H_{22}O_{11}$. That these bodies are compounds and not mixtures is proved by their being incapable of separation by the action of alcohol, whereas mixtures of dextrin and maltose in the same proportions are readily so separated. Further, the amyloïns are unacted on by ordinary yeast, *Saccharomyces cerevisiæ,* while the maltose of a *mixture* is readily so fermented. They are completely converted by diastase into maltose.

191. Amylo-dextrin, $\left\{\begin{matrix}C_{12}H_{22}O_{11}\\(C_{12}H_{20}O_{10})_6\end{matrix}\right.$—This body is produced by the action of dilute acids on starch granules in the cold. After some weeks' treatment the corpuscles become completely disintegrated, and then consist largely of amylo-dextrin; this is dissolved in hot water and purified by precipitation with alcohol. This substance is a definite chemical compound, having the formula above assigned to it as the result of a determination by Raoult's method; and is produced by the hydrolysis of starch. Amylo-dextrin gives an intense reddish-brown colouration with iodine, and its presence is the cause of the chemical properties hitherto ascribed to erythro-dextrin.

192. Malto-dextrin, $\left\{\begin{matrix}C_{12}H_{22}O_{11}\\(C_{12}H_{20}O_{10})_2\end{matrix}\right.$ —When starch is converted by diastase, malto-dextrin is found to a greater or lesser extent in the products, especially when the converting action is not very prolonged. Malto-dextrin is unfermentable by ordinary yeast, *Saccharomyces cerevisiæ*, by the action of which it may be distinguished, and separated, from maltose. Malto-dextrin is, however, slowly fermented by certain secondary yeasts. Malto-dextrin cannot be separated into its constituents by the action of alcohol, but diastase completely and readily converts it into maltose.

193. Other Carbohydrates of Cereals.—There are certain other carbohydrate bodies, of which small quantities are found in wheat and other grains; among these are:—

Raffinose, $C_{18}H_{32}O_{16}5H_2O$, is a sugar somewhat resembling cane sugar in character, but less easily inverted. Found by O'Sullivan in barley.

α and β Amylan, $nC_6H_{10}O_5$, are two bodies having the same empiric formula, which are found in the mucilaginous portions of grains. They are almost insoluble in cold water, dissolve in hot water, and gelatinise on cooling. These substances, when treated with dilute acids, are converted into glucose without the production of intermediate bodies. Wheat contains from 0.1 to 0.05 per cent. of α amylan, and from 2.0 to 2.5 per cent. of β amylan.

Extractive Matters.—Under this heading are included certain substances which cannot be readily identified in the same manner as starch, maltose, and other bodies. This is in consequence of their possessing no very definite chemical reactions. Lintner has obtained from barley a white amorphous substance of a gummy nature, to which the name xylan has been given, and which in composition is represented by the formula, $C_{11}H_{20}O_{10}$.

Experimental Work.

194. Cellulose.—Mix in a moderate sized beaker about 5 grams of wheat meal, with 150 c.c. of water, and 50 c.c. of a 5 per cent. solution of sulphuric acid; and set the beaker in a hot water bath for half an hour, giving its contents an occasional stir. At the end of that time add 50 c.c. of a 12 per cent. potash solution, and set the beaker in the bath for another half-hour. Observe that a residue remains; allow this to subside, and wash it by decantation. Finally, transfer it to a filter, and let it drain. The substance thus obtained consists of the cellulose or woody fibre of the wheat. Add iodine solution to a portion, and notice that it produces no blue colouration.

It is assumed that most of the students who go systematically through this course of experimental work will do so in a regularly appointed laboratory; they will there find the solutions of sulphuric acid and potash above referred to ready made up for use. Full directions for their preparation, and also of other special reagents required, are given in the chapters on analytic work toward the end of the book. Unless he has not access to such solutions, the student need not at this stage of his work trouble to specially prepare them.

195. Microscopic Examination of Starches.—Take a small quantity of either wheat meal or flour and make it into a dough. Tie this up into a piece of muslin or bolting silk, and knead in a small cup or glass with water; the starch escapes, giving the water a milky appearance, while the gluten and bran remain behind in the muslin. Clean an ordinary microscopic glass slide and cover, shake the starchy water and place a minute drop on the slide, lay on the cover, press it down gently, and soak up any moisture round its edge with a fragment of blotting paper. Place the slide on the microscopic stage, and focus the instrument, using first the inch and then the quarter or eighth objective. The separate starch cells are then plainly seen. Trace in a few of the cells on paper, with a camera lucida, and sketch in any points of detail. Measure one or two of the cells with the eye-piece micrometer, and mark their dimensions on the drawing.

Take a small quantity of the flours respectively of barley, rye, rice, and maize, wash out the starch from each, and examine microscopically in precisely the same manner as with the wheat, making drawings in each case. A little corn flour, being practically pure maize starch, may be used instead of maize flour. Cut a potato in halves, and with a sharp knife scrape off a little pulpy matter from the cut surface, transfer to a slide, and examine with the microscope.

Notice in each case the relative sizes of the granules, and compare their shapes. Examine for the hilum and also observe the rings. If the microscope be fitted with polarising apparatus, study the various starches under polarised light.

196. Examination of Mixed Starches.—With separate portions of wheat flour, mix respectively small quantities of rice meal and corn flour. As before, knead the starch out of each, and examine the milky fluid for the foreign starches. Notice in the one case the very small rice starch granules, and in the other the somewhat larger maize starch granules interspersed among those of the wheat.

197. Gelatinisation of Starch.—Heat separate quantities of one gram of the starches of wheat, rye, maize, rice, and potato in 50 c.c. of water; and notice the temperature at which the liquids commence to thicken through gelatinisation of the starch. The experiment is conducted in the following manner:

Place a moderately large beaker on a piece of wire gauze over a tripod, as in Fig. 8. Take several small beakers or test tubes, and attach to each a wire hook, so that they may be hung over the edge of the large beaker. Fill this large beaker with water, and use it as a water bath. Put the starch to be tested, together with the requisite quantity of water, in one of the small beakers, and suspend it in the water bath; under which place a lighted bunsen. While the small beaker is thus being heated, stir its contents with a thermometer, and note the temperature at which the first appearance of gelatinisation is detected; instantly remove the beaker and plunge it into a vessel of cold water. When cold, examine a little of the paste with the microscope, and notice whether or not many of the granules remain unaltered. Make a second experiment with the same starch, arresting the temperature at 2° hotter or colder, according to the degree of gelatinisation revealed by the microscope on the first trial. All the starches specified are to be tested in the same manner.

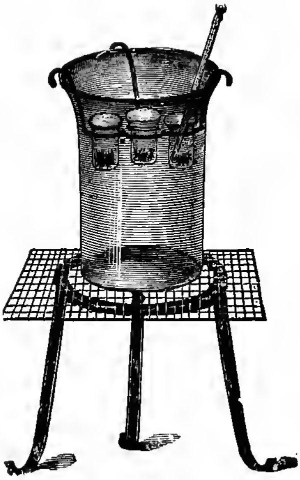


Fig. 8.—Apparatus for determining Temperature of Gelatinisation of Starch.

198. Reactions of Starch Solution.—Gelatinise a little starch by heating it with water in a test tube or small beaker placed in the hot-water bath; then let the solution cool.

Dissolve some iodine in alcohol, and aqueous solution of potassium iodide, respectively. In each case use sufficient iodine to just give a sherry tint to the solution. Add some of either of these solutions (that in alcohol is commonly called a "tincture") to a small quantity of the solution of starch; notice the blue colour produced. Heat the solution, and then allow it to cool; observe the disappearance and gradual re-appearance of the colour.

Render a portion of the starch solution alkaline by the addition of caustic soda or potash; to one portion of this solution add iodine; notice that no colouration is produced. To the other, add dilute sulphuric acid until the solution is slightly acid to litmus paper. Then add some iodine solution, and observe that the normal blue colour is produced. Add respectively solution of iodine in potassium iodide, and the tincture of iodine, to separate small portions of flour; notice the dark blue colour produced in the first instance, and the sherry tint in the second. To the second portion add a little water; the dark blue colour at once appears. Mount a minute portion of flour on a slide with iodine solution; examine under the microscope, and notice the blue colouration of the starch granules, while other constituents of the flour remain comparatively uncoloured.

199. Dextrin.—Render some water faintly acid by the addition of a small quantity of nitric acid; with this, moisten some starch in a porcelain dish, and maintain it at a temperature of 200° C. in a hot-air oven for about two hours. The hot-air oven is usually made of copper, and is heated by means of a bunsen placed underneath; through a hole in the top a thermometer is fixed so as to show the temperature. Before using the oven, regulate the temperature by turning the bunsen partly on or off until the thermometer remains steadily within say 10 degrees of 200. The moistened starch must not rest direct on the bottom of the oven: it may be placed on a small tripod made by turning down the wires of an ordinary pipe-clay triangle.

Treat this heated starch with hot water, and filter; a yellowish-brown gummy solution is obtained. To a portion, add iodine solution; notice that no blue colouration is produced, but instead a reddish-brown tint; starch, therefore, is absent. The reddish-brown colour is due to the presence of amylo-dextrin. From another portion of the solution, precipitate the dextrin by adding strong alcohol; filter and wash the precipitate with alcohol, dissolve in a little water and reserve for a future experiment. Use a little of the solution for fastening together pieces of paper; notice that it exhibits the ordinary properties of gum.

200. Maltose and other Sugars.—Take from 5 to 10 grams of ground malt, and mix with ten times the quantity of water, place the mixture in a beaker arranged in a hot-water bath, and keep it at a temperature of 60° C. for half an hour: this may be done by turning down the flame, or altogether removing it from time to time. The temperature may range from 55 to 65° C., but must not be allowed to go above the latter. At the end of the half-hour, raise the temperature to the boiling point for five minutes, and then filter; the resultant liquid is a solution of maltose and dextrin, and may be used for experiments on maltose.

Prepare solutions of the following substances, and test them with Fehling's solution: (1), starch; (2), the re-dissolved alcoholic precipitate of dextrin; (3), aqueous extract of malt; (4), cane sugar; and (5), commercial glucose.

Set some distilled water boiling in a flask or large beaker for half an hour. Take 20 c.c. of the mixed Fehling's solution (see Chapter XXIV.), add an equal quantity of the boiled distilled water, and set in the boiling hot-water bath for ten minutes; notice that no precipitate is produced. Heat five separate portions of 20 c.c. of Fehling's solution, and 20 c.c. of water to the boiling point, and add respectively 20 c.c. of the starch and other solutions previously prepared. Let them all stand in the hot-water bath for ten minutes: at the end of that time some of the solutions will probably be decolourised with the deposition of a copious red precipitate, while others will remain unchanged. The results should be as follows:—

Starch—No precipitate.
Dextrin—Very slight precipitate, due partly to the slight reducing action of dextrin itself, and partly also to the difficulty of thoroughly washing the dextrin free from maltose.
Maltose—Red precipitate.
Cane sugar—No precipitate.
Glucose—Red precipitate.

CHAPTER VII.

THE PROTEINS.

201. Character of Proteins.—The proteins, while not the most abundant constituents of wheat and flour, are yet among the most important. In whatever life exists, and in that physical basis of life, protoplasm, proteins are constantly and invariably present. In matters of animal origin, such as muscle, blood, milk, the proteins constitute a larger proportion of the water-free material than in most vegetable bodies, and much of the work of examining and classifying proteins has been first done on those derived from animal sources. All animal proteins are, however, derived either directly, or indirectly through the body of some other animal, from the proteins of the vegetable kingdom. The name protein is derived from the Greek word for pre-eminence, and has been given to these bodies because of their great importance in the animal economy. Typical among the protein bodies is albumin, the essential constituent of the white of egg; so much so that the term "albuminous" substance was often used as a synonym of protein. With a more minute classification of the proteins, the term albumin was restricted to one particular protein group; and the term "albuminoid," commonly employed as bearing the same meaning as "protein," was restricted to gelatin and certain other bodies which are not proteins, but bodies bearing a resemblance or relationship to the group of which albumin is the typical member.

202. Nomenclature of the Proteins.—The proteins were formerly known as proteids, but in view of the confusion arising from the lack of understanding as to the exact sense in which the various names applied to proteins should be used, the Physiological Society and the Chemical Society conjointly considered the subject through a Committee nominated by the two Societies. Their final report contained the following recommendations:—

I. The word Proteid should be abolished.

II. The word Protein is recommended as the general name of the group of substances under consideration. If used at all, the term Albuminoid should be regarded as a synonym of protein. The substances gelatin and keratin, which have hitherto been termed albuminoids in the limited sense in which physiologists have been accustomed to use it, should be called sclero-proteins (*Proc. Chem. Soc.*, 1907, xxiii, 55).

This restricted use of the term "albuminoid" has not, however, been universally adopted, as the word is still used as meaning the same as protein, while in more recent nomenclature the name has been appropriated to a small sub-group of "simple proteins."

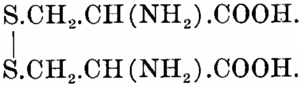
203. Composition of Proteins.—The proteins are distinguished in composition from the carbohydrates by their containing nitrogen and in most cases sulphur as essential constituents, in addition to carbon, hydrogen, and oxygen. They are substances of extremely complex constitution, and have very high molecular weights. They are colloid bodies, and for the most part uncrystallisable. The various proteins differ somewhat in composition: the following table gives the ranges of variation in percentages:—

	C	H	N	S	O
From	50.0	6.9	15.0	0.1	20.9
To	55.0	7.3	19.0	2.0	23.5

From these figures various observers have attempted to assign empiric formulæ to the proteins, but in this there is some difficulty, as methods such as that of Raoult, which was so useful with the carbohydrates, cannot be applied to the proteins. Compounds are, however, known of egg albumin with copper, and of seed globulins with magnesium and other metals, and from these some idea of the complexity of the protein molecule can be gained. Thus the compound of one atom of copper with egg albumin has the following formula: $CuC_{204}H_{322}N_{52}S_2O_{66}$, while from the globulin metallic compounds the formula, $C_{292}H_{481}N_{90}S_2O_{83}$, has been suggested for globulin. Plimmer gives $C_{726}H_{1174}N_{194}S_3O_{214}$ as the formula of globin, the basis of hæmoglobin.

Within the last ten years Fischer and his co-workers have done much to make clear the actual constitution of the proteins. Plimmer in his monograph on the Chemical Constitution of the Proteins remarks that: "The main results of these [Fischer's] investigations is that the protein molecule is built up of a series of amino-acids, which form the basis of their composition, and of which [some eighteen] have been definitely determined." By the condensation together, or combination with the elimination of molecules of water, the amino-acids are converted into a class of products which Fischer terms the "polypeptides." These form an essential part of the protein molecule, which may also, however, contain other groups such as phosphoric acid or possibly carbohydrates.

Among the amino-acids which occur in proteins is a thio- or sulpho-acid, known as cystine, which is di- β-thio-α-amino-propionic acid), and may be represented by the formula—



$$\begin{array}{l} S.CH_2.CH(NH_2).COOH. \\ | \\ S.CH_2.CH(NH_2).COOH. \end{array}$$

Recent research has shown that cystine is the only sulphur-containing compound in the protein molecule, and consequently that the number of sulphur atoms in such molecule must be two or a multiple of two. As sulphur is found in all proteins (except the protamines and histones), it follows that they must all contain cystine as an essential constituent.

204. Reactions of Proteins.—Protein substances are distinguished by their evolving ammonia on being strongly heated. This is at once noticed on burning pieces of quill or dried gluten, both of which consist largely of protein bodies. If the suspected substance be heated to near the boiling point of concentrated sulphuric acid, to which a little potassium sulphate has been added, the whole of its nitrogen is converted into ammonium sulphate, from which free ammonia is obtained by adding caustic soda in excess, and subjecting the liquid to distillation. This reaction forms the basis of what is known as Kjeldahl's method for the determination of nitrogen in organic compounds. In examining substances for proteins, and especially in discriminating the various proteins from each other, their following characters are of importance—solubility, heat coagulation, indiffusibility, action on polarised light, and colour reactions.

Solubility.—All proteins are insoluble in absolute alcohol and in ether. Some are soluble in water, others insoluble; among the latter, many are soluble in weak saline solutions. Some proteins are soluble and others insoluble in strong or saturated saline solutions.

Mineral and acetic acids, and also caustic alkalies, dissolve all proteins by the aid of heat, such solution being, however, accompanied by decomposition. The gastric and pancreatic juices also dissolve proteins, but, in so doing, change them into a sub-class of proteins, known as peptones.

Heat Coagulation.—This is a very familiar characteristic of some proteins, chief among them being albumin from the white of egg, which on being plunged into boiling water assumes an insoluble form. Many proteins when dissolved either in water or dilute saline solutions are coagulated by the action of heat. The temperature at which coagulation occurs affords one method of determining the nature of the particular protein in the solution. Distinct from heat coagulation is what is known as ferment coagulation, an instance of which is the coagulation of milk by rennet.

Indiffusibility.—All the proteins (with the exception of the peptones) are highly colloid bodies, and when in solution may consequently be separated from crystalline bodies by dialysis.

Action on Polarised Light.—All proteins turn a ray of polarised light to the left, or are lævo-rotatory.

Colour Reactions—Xanthoproteic Reaction.—These are very useful methods of detecting and recognising proteins. The Xanthoproteic reaction is obtained in the following manner: Add to the solution under examination a few drops of strong nitric acid; a white precipitate may or may not be produced, according to the nature and degree of concentration of the protein. (Peptones and some varieties of albumose give no precipitate.) Boil; the precipitate or liquid turns yellow, with usually some solution of any precipitate. Cool and add ammonia; the yellow liquid or precipitate turns orange. This colouration is the essential part of the reaction, and is the most delicate test for proteins we possess.

Millon's Reaction.—Dissolve, by the aid of gentle heat, one part by weight of mercury in two of strong nitric acid; dilute with twice its volume of water, and allow the precipitate to settle; the clear supernatant liquid is Millon's reagent. On the addition of a few drops of this to a solution of protein, a white precipitate forms, which, on being heated, assumes a brick-red colour. The reaction is prevented by the presence of sodium chloride. Other substances are precipitated by Millon's reagent, but the precipitate does not turn red on boiling.

Piotrowski's or "Biuret" Reaction.—Add to the solution of albumin or similar protein a few drops of dilute solution of copper sulphate; a precipitate of copper albuminate is formed, except with deutero-albumose and peptone. Add excess of caustic potash or soda, a violet solution is produced. Ammonia gives a blue solution.

In the case of albumoses and peptones, the result is, instead, a rose-red solution with potash, and a reddish-violet with ammonia. Care must be taken not to add excess of sulphate, as so doing gives a reddish-violet colour, very difficult to distinguish from this peptone reaction. When this test is applied in the presence of salt solutions it may be somewhat modified: thus, magnesium sulphate is precipitated as magnesia by potash; before the colour can be observed the precipitate must be allowed to subside. If ammonium sulphate is present, a large quantity of potash is necessary before the colour appears; sodium chloride does not affect the reaction.

205. Precipitation of Proteins.—The preceding note on the solubility of proteins affords some clue to their various modes of precipitation, the peptones and albumoses being much more soluble than other proteins.

Solutions of the proteins may be precipitated by the following bodies:—Strong mineral acids, especially nitric acid; acetic acid; and also with excess of sodium sulphate, sodium chloride, or magnesium sulphate. Salts of the heavy metals, as mercuric chloride or basic lead acetate, also precipitate proteins; on suspending the precipitate in water, and passing a stream of sulphuretted hydrogen, the metal is precipitated and the protein recovered in an unchanged form. In addition, proteins are precipitated by tannin, or tannin and sodium chloride together; by saturation with ammonium sulphate; by picric acid; and by alcohol in faintly acid solutions.

Among these the following are convenient methods of removing proteins from a solution, either as a part of the process for their own isolation, or as a prior step toward examining the liquid for other substances:—

1. The solution is mixed with half its volume of a saturated solution of common salt, tannin is added in slight excess, and the proteins are entirely separated.
2. The solution is saturated with ammonium sulphate, which precipitates all proteins but peptones.
3. The solution is rendered faintly acid with acetic acid, several times its volume of absolute alcohol added, and allowed to stand twenty-four hours. The whole of the proteins are thus precipitated.
4. When proteins of the albumin or globulin group only are present, simple acidulating and boiling the solution precipitates the proteins.

206. Classification of Proteins.—Proteins are commonly divided into animal and vegetable proteins, according to their origin. Strictly speaking, the animal proteins have but little to do with the present work, but as their classification is largely that on which the classification of those from vegetable bodies is also based, a short account of the animal proteins is here inserted.

207. Animal Proteins.—These are conveniently arranged in the following groups:—

Class 1. *Albumins,* soluble in water, in dilute saline solutions, and saturated solutions of sodium chloride and magnesium sulphate. Precipitated from their solutions by saturation with ammonium sulphate. Coagulated by heat, usually about 70°-73° C.

Members of class—Serum albumin, egg albumin, cell albumin, muscle albumin, lact-albumin.

Class 2. *Globulins,* soluble in dilute saline solutions; insoluble in water, concentrated solutions of sodium chloride, magnesium sulphate, and ammonium sulphate. Coagulated by heat, temperature varying considerably.

Members of class—Fibrinogen, serum globulin, crystallin; vitellin, in the yolk of egg, not precipitable by sodium chloride.

Class 3. *Albuminates, or Derived Albumins,* derived from either albumins or globulins by the action of weak acids or alkalies. On heating a solution of egg albumin to about 40° C. with a few drops of 0.1 per cent. sulphuric acid or 0.1 per cent. potash solution, the solution loses its properties and becomes converted into acid-albumin or syntonin, or alkali-albumin respectively.

Albuminates are soluble in acid or alkaline solutions or in weak saline solutions; insoluble in pure water, precipitated like globulins by saturation with sodium chloride, magnesium sulphate, or ammonium sulphate. Solutions not coagulated by heat.

Caseinogen, the chief protein constituent of milk, is an albuminate.

Class 4. *Proteoses,* intermediate products in the hydration of proteins, formed in the body by the action of the gastric and pancreatic juices, artificially by heating with water, and more readily by dilute mineral acids. Are not coagulated by heat, precipitated by alcohol, all give the biuret reaction. Precipitated by nitric acid, precipitate soluble on heating, and reappearing as the liquid cools.

The proteoses are subdivided into albumoses, globuloses, etc., according to the original protein from which derived, albumin, globulin, etc. Each group of proteoses may be further subdivided in a similar manner; taking albumose, there are two varieties, *hemi-albumose* and *anti-albumose,* which on further digestion are converted into hemi-peptone and anti-peptone respectively. Classified according to their solubilities, they are divided into—

Proto-albumose, soluble in cold and hot water and in saline solutions; precipitated like globulins by saturation with sodium chloride or magnesium sulphate.

Hetero-albumose, insoluble in water; soluble in 0.5-15 per cent. sodium chloride solution in the cold, but precipitated by heating to 65°. Precipitated from its solutions by dialysing out the salt, like globulins. Precipitated by saturation with salts. Proto- and hetero-albumose are often called primary albumoses, because they are the first products of hydration of proteins.

Deutero-albumose, soluble in hot and cold water, not precipitated from its solutions by saturating with sodium chloride or magnesium sulphate, but precipitated by ammonium sulphate, is an intermediate stage in the conversion of the primary albumoses into peptone.

Class 5. *Peptones* are the final product of the hydration of proteins; further hydration splits up the peptone into simpler bodies, which are no longer proteins. The peptones are soluble in water, not coagulated by heat, and are not precipitated by nitric acid, copper sulphate, ammonium sulphate, and a number of other precipitants of proteins. Precipitated, but not coagulated, by alcohol. Precipitated by tannin, picric acid, and other substances. They give the biuret reaction.

Pure peptone may be separated from all other proteins by ammonium sulphate: the solution is then subjected to dialysis in order to remove the sulphate, and the peptone precipitated by alcohol. It may then be dried by washing with absolute alcohol, ether, and finally standing in desiccator over sulphuric acid, a vacuum being maintained in the desiccator by a sprengel or other air-pump. Peptone thus prepared hisses and froths on being dissolved in water, with evolution of heat.

Peptone is somewhat cheesy in taste, but not unpleasant. Artificially prepared peptones, as peptonised milk or beef extract, have a bitter taste. This is due, however, to some bitter substance not yet separated, native peptones and albumoses being almost tasteless.

Hemi-peptones are split up by the pancreatic juice into simpler products, as leucine and tyrosine. Anti-peptone is not decomposed in this manner.

Both varieties of peptone are readily dialysable; albumoses are only slightly diffusible under similar conditions, while the albumins and globulins are highly colloid.

Class 6. *Coagulated Proteins.*—(*a*) Coagulated by heat, are insoluble in water, weak acids, and alkalies. Soluble after prolonged boiling in concentrated mineral acids, also in gastric and pancreatic juice with formation of peptones. (*b*) Coagulated by ferments, fibrin from blood, myosin from muscle, casein from milk.

208. Vegetable Proteins.—As previously stated, plants contain a less proportion of protein matter than animals. They may be found in solution in the sap or juice of plants, or in the solid state in the protoplasm of the plant cells, and in a comparatively dry condition in the ripe seeds. Protein is often found in granules (aleurone grains). Some of the vegetable proteins are obtainable in a crystalline form. The classification adopted for the animal proteins is in the main applied to those of vegetable derivation.

209. More Recent Official Classification.—In the years 1907 and 1908 committees were appointed by scientific societies in America and England respectively in order to settle a scheme of classification and nomenclature of the proteins. The American scheme was of the two the more complete, inasmuch as it definitely provided for the inclusion of the vegetable proteins. Their classification contained the following groups:—

I. The Simple Proteins.
- (*a*) Albumins.
- (*b*) Globulins.
- (*c*) Glutelins.
- (*d*) Alcohol-soluble Proteins (Prolamins).
- (*e*) Albuminoids.
- (*f*) Histones.
- (*g*) Protamines.

II. Conjugated Proteins.
- (*a*) Nucleoproteins.
- (*b*) Glycoproteins.
- (*c*) Phosphoproteins.
- (*d*) Hæmoglobins.
- (*e*) Lecithoproteins.

III. Derived Proteins.
1. Primary Protein Derivatives—
   - (*a*) Proteans.
   - (*b*) Metaproteins.
   - (*c*) Coagulated Proteins.
2. Secondary Protein Derivatives—
   - (*a*) Proteoses.
   - (*b*) Peptones.
   - (*c*) Peptides.

Although the classification of the vegetable proteins largely follows that of animal proteins, the special character of those of vegetable origin necessitates some little modification of the definitions as deduced from the investigation of the animal compounds.

The following explanations of the various classes are made with special reference to the vegetable section, and do not agree in every detail with the properties already given of the animal groups.

210. Simple Proteins.—*Albumins.* These have been already defined as "soluble in water and coagulated by heat," but a more recent classification has been based upon the behaviour of albumins and globulins respectively to a half-saturated solution of ammonium sulphate. The portion of protein which under these conditions remains in solution is regarded as albumin. This does not hold good with the vegetable albumins, since some at least are precipitated by this treatment. Again, in the case of the vegetable albumins it is often difficult to say whether such a body is soluble in pure water, or whether its solubility is due to the presence of small quantities of mineral salts. One of the best studied vegetable albumins is the leucosin of wheat, and this is soluble in water containing merely the slightest traces of mineral matter. The following are examples of vegetable albumins:—

Leucosin from the seeds of wheat, rye and barley.
Legumelin from the seeds of pea and lentil.

Globulins.—The previous definition of these states them to be "insoluble in water, soluble in dilute saline solutions"; but among the vegetable globulins are classed certain bodies which only have the properties of the globulins when existing as protein salts through combination with small quantities of acid. On being freed from this acid, they become soluble in water, and thus no longer conform to the definition of the class. From their mode of preparation it is nevertheless convenient to include them in this group.

Globulins were formerly subdivided into two groups according to whether or not they can be precipitated from a solution by saturation with sodium chloride. This operation, known technically as "salting-out," separates the bodies known as myosins from solution. Those remaining unchanged were termed vitellins. In the case of the vegetable globulins, this distinction does not hold good, as certain so-called myosins are in fact albumins, while some vegetable vitellins are only partly soluble in saturated sodium chloride solution. The body referred to as wheat myosin is really the albumin leucosin. All vegetable globulins, so far as has been at present ascertained, are completely precipitated by saturation with sodium sulphate at a temperature of 33° C. The animal globulins may all be coagulated by heat, but most of those of seeds are only imperfectly coagulated by heating their solutions even to boiling. A characteristic of a number of the vegetable globulins is that they may be obtained in a crystalline form, while others can be separated as minute spheroids. The following are examples of vegetable globulins:—

Legumin from the seeds of pea and lentil.
Tuberin from the tubers of potato.
Unnamed globulin from the seeds of wheat.

The globulin of wheat is mostly if not all contained in the embryo or germ.

Glutelins.—These consist of proteins which are insoluble in neutral aqueous solutions, saline solutions, or moderately concentrated alcohol (about 70 per cent. spirit). The most characteristic and only well explored member of this group is the glutenin of wheat. Similar proteins probably exist in other seeds, such as those of rye and barley, and also, according to Rosenheim and Kajiura, in rice. The rice glutelin has received the name oryzenin, and is said to represent the greater portion of the protein of the seed.

Prolamins.—Certain seed proteins are soluble in alcohol of from 70 to 90 per cent. strength. Representatives of this group have been obtained from all seeds of cereals except rice; further, they have never been found in the seeds of any other family of plants. The suggestion has been made that these proteins should be called "gliadins," but as that name has already been appropriated to alcohol-soluble protein of wheat, Osborne has proposed the group name of "prolamins," because on hydration they yield considerable quantities of proline and amide nitrogen. The following are examples of prolamins:—

Gliadin from the seeds of wheat and rye.
Hordein from the seeds of barley.
Zein from the seeds of maize.

Albuminoids, etc.—The remaining simple proteins, albuminoids, histones, and protamines, are not found to occur in plants.

211. Conjugated Proteins.—*Nucleoproteins.* These bodies, called also nucleins, occur in the cells of animals and plants. Thus yeast yields a body represented, according to Miescher, by the formula $C_{29}H_{49}N_9P_3O_{22}$. This substance contains phosphorous in considerable quantity (9 per cent.), and is extremely resistant to the action of pepsin. Nucleoproteins may be regarded as compounds of nucleic acid with the proteins, which latter have been shown to have basic properties. Nucleic acid, in turn, is viewed as a compound of albumin with phosphoric acid. Nucleoproteins are found in the protein constituents of wheat germ.

Glycoproteins.—These bodies are proteins, containing either a carbohydrate or carbohydrate generating group within their molecule. There is, however, no definite evidence of the occurrence of glycoproteins in plants.

Phosphoproteins.—Egg yolk contains a protein of the globulin type, of which phosphorus is an essential ingredient, and to which the name of vitellin has been given. It has been assumed that certain vegetable proteins are also of this class; but vitellin may be repeatedly redissolved and re-precipitated without losing its phosphorus, whereas vegetable proteins containing phosphorus are thereby completely freed from that element. The conclusion is that the existence of true vegetable phosphoproteins has not as yet been proved.

Hæmoglobins, etc.—It is doubtful whether any hæmoglobins have been obtained from plants, while lecithoproteins are also probably absent from their constituents.

212. Derived Proteins.—*Primary Protein Derivatives.* Substantially, by the action of dilute acids and alkalies, the vegetable proteins undergo similar changes to those of animal origin when treated in a like manner. The derived proteins are the bodies already described as Class 3 of animal proteins.

The proteans and metaproteins do not need description as a part of the present work.

Coagulated proteins.—Many of the proteins possess the property of coagulation by heat, especially in the presence of a small quantity of free acid. This holds good much more with those of animal origin, for the corresponding seed proteins are in most cases only imperfectly coagulated by heating their solutions even to boiling. Thus leucosin from wheat, when obtained in solution by the extraction of wheat flour with water, is partly coagulated at a temperature of 52° C., but is not entirely so changed even at the boiling point.

Secondary Protein Derivatives.—Small quantities of proteoses are found in seeds, but it is difficult to say whether these existed as such in the seeds, or have been produced by changes which have occurred during the processes involved in their separation. Present evidence is not sufficient to exclude the possibility of such changes, and therefore to demonstrate their existence as original components of the seeds.

The same difficulties exist in the way of deciding whether or not peptones occur in plants. They may be formed from vegetable proteins by boiling with dilute mineral acids, or treatment with gastric or pancreatic juices. Animal proteins are, as a rule, more easily peptonised than those of vegetable origin; thus papain, a vegetable enzyme, converts animal proteins into peptones, but carries the change of vegetable proteins no further than proteoses.

213. Albuminoids.—With the proposal, not universally adopted, to restrict this term to a series of bodies outside the protein group, it will be well to briefly state the character of albuminoids in this more restricted sense. The tendons of animals contain a body known as "collagen," which is insoluble in water. By the action of dilute acids or boiling water, collagen is transformed into gelatin: the process is one of hydration, represented, according to Hofmeister, by the following equation:—

$$\underset{\text{Collagen.}}{C_{102}H_{149}N_{31}O_{28}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Gelatin.}}{C_{102}H_{151}N_{31}O_{29}}.$$

The albuminoids, as thus classified, differ from the proteins in that they contain no sulphur. Gelatin is insoluble in cold water, but dissolves in hot water, gelatinising, or forming a jelly, on cooling.

214. Proteins of Wheat.—It is a fact too familiar to need experimental demonstration, that the white of egg coagulates on being heated; but it will be found on further experiment, as may in fact be gathered from the preceding description, that if the white of egg be shaken up with considerable quantities of water and then heated, the albumin separates out in coagulated flocks. Similarly on making a cold aqueous infusion of flour, or, still better, of the germ of wheat, and then filtering the solution until perfectly clear, a liquid is obtained which, on being raised to the boiling point, throws down abundant flocks of albumin and globulin. The coagulated protein thus obtained is as white and pure in appearance as that from the white of egg, and is closely allied to that of mixtures of albumin and globulin of animal origin. While the egg albumin always occurs in an alkaline liquid, that of vegetables is always found either in acid or neutral liquids.

Further, every miller and baker knows that flour, on being moistened, forms a stiff, tenacious paste or dough; he also knows that the flour of wheat is distinguished in a remarkable manner from other flours by this character; for oatmeal, when similarly treated, simply produces a damp mass, having little or no tenacity. On kneading a mass of wheaten dough, enclosed within a piece of muslin, with water, until the starch is separated, there remains behind a greyish-white sticky elastic mass, to which the name of "crude gluten" is applied. This substance consists of the insoluble proteins of the wheat, together with portions of the ash, carbohydrates, and oily matter. Although this gluten, when in the flour, existed as a powder, yet, on the addition of water, it thus swells up into a tough mass. Gluten is practically insoluble in water, and without taste; on being dried by exposure to the heat of the hot-water oven, it changes into a hard horny mass. Gluten which has been thus moistened with water, provided it is dried at a low temperature, swells up again on being wetted, although not usually to such a tough mass as when first extracted. Osborne, with whom has been associated a number of other chemists, has for some years been engaged in a systematic investigation of the vegetable proteins; in 1893 he, in association with Voorhees, communicated to the *American Chemical Journal* an article of great importance on "The Proteids [Proteins] of the Wheat Kernel." This article contains a historical résumé of the work previously done on these compounds, and also includes the results of their own elaborate investigations on wheat proteins, conducted on the lines of the most recent knowledge of the constitution of proteins generally. The following description is very largely based on Osborne and Voorhees' article, which is still the most authoritative exposition of the properties of the wheat proteins. It is, in fact, not too much to say that science generally is indebted to Osborne for most of the work that has as yet been done on the vegetable proteins.

215. Earlier Researches.—After recounting the results of the researches of Taddei, Berzelius, Mulder, Gunnsberg, and others, Ritthausen's conclusions are mentioned, in which that chemist recognised in 1872 that wheat contains five protein bodies, to which he gave the names of gluten casein, gluten fibrin, plant gelatin or gliadin, mucedin, and albumin. He expressed a doubt as to the presence of albumin, as what was viewed as this body might possibly be a mixture of mucedin and gliadin.

In 1880, Weyl and Bischoff published the view that the protein matter of wheat is principally a myosin-like globulin, which they call vegetable myosin, and, if this view be correct, they further assume that it is from this substance that gluten is derived, other proteins only being present in small quantity. They extracted flour with a 15 per cent. salt solution. and found that the residue yielded no gluten; they consequently assumed that gluten is formed from myosin as a result of a ferment action similarly to the formation of blood-fibrin from fibrinogen. No ferment possessing such properties could, however, be detected. Large quantities of sodium chloride and other salts prevent the formation of gluten in the same way as these salts also prevent the formation of fibrin. On first heating flour with alcohol, they found that subsequently no gluten could be obtained on washing, and so assumed that the myosin had been coagulated. Also, on warming flour for from 48 to 96 hours, keeping the temperature below 60° C., the coagulation point of myosin, and then adding a little unwarmed flour and extracting gluten from the mixture, no gluten is obtained beyond that present in the added flour, showing in Weyl and Bischoff's opinion that the gluten-forming substance had suffered coagulation.

Martin in 1886 examined gluten by extraction with alcohol—he found but one protein substance so extracted. This body is soluble in hot water, but is insoluble in cold, and so is insoluble phyt-albumose. The residue insoluble in alcohol is uncoagulated protein, soluble in dilute acids and alkalies; this he terms gluten-fibrin. The insoluble phyt-albumose is not present as such in flour, as direct extraction of the meal with 75 per cent. alcohol removes no protein. Martin concluded that the insoluble phyt-albumose is formed from the soluble by the action of water, the gluten-fibrin being formed by a similar action of water on the globulin, that is, conversion into an albuminate. The albuminate and insoluble phyt-albumose together constitute gluten.

Johannsen, 1889, combats the ferment theory of the production of gluten. He found that a normal dough was obtained by grinding dried gluten and mixing with starch, and also by mixing moist gluten with starch.

216. Osborne and Voorhees' Experiments, Wheats used.—One of these was a Minnesota spring wheat, Scotch Fife, milled under chemical supervision into "patent" flour from finest and purest middlings, and "straights" from the coarser middlings. The "shorts" (red-dog?), chiefly composed of inner portions of the bran, with adhering portions of the endosperm, was also examined. Samples of whole wheat flour were prepared direct from the wheat by grinding in the laboratory when required. A variety of winter wheat, known as "Fultz," was also examined, but only as whole wheat flour. Preliminary investigations showed that all these different flours yielded protein matter to—

Diluted alcohol,
Water,
10 per cent. sodium chloride solution,
And after complete and successive extractions with these reagents, to dilute potash water.

The bodies extracted by these various reagents will be examined separately.

217. Proteins Soluble in Water.—In the course of some preliminary experiments, 200 grams of spring wheat straight flour were mixed with 800 c.c. of distilled water. No coherent gluten formed, the undissolved flour settling down as a non-coherent mass. After a few hours' digestion the solution was filtered; the filtrate was straw-yellow in colour, becoming red-brown on standing, and had a *very* slight acid reaction.

Saturation with ammonium sulphate gave a bulky precipitate, which contracted on standing, showing the solution to contain but little protein matter. After 24 hours this precipitate was completely soluble in water, giving no evidence of the formation of so-called albuminates. Saturation with sodium chloride gave a small precipitate. Acetic acid in the cold gave no precipitate until sodium chloride was added.

On slowly heating, the solution gave a turbidity at 48° C., and a flocculent coagulation at 52°. After heating to 65° for some time and filtering, the solution became turbid again at 73°, flocks forming in very small amount at 82°. Heating to boiling caused no further separation; but the addition of a little acetic acid and sodium chloride gave a small precipitate. The body coagulating at 52° formed the greater part of the protein in solution. The complete coagulation of this required a temperature of 65°, but was greatly facilitated by the addition of sodium chloride.

Further experiments showed that extraction of the flour with 10 per cent. salt (sodium chloride) solution yielded the same proteins, so that the subsequent examination of the water-soluble substances was confined to extracts originally made with 10 per cent. salt solution after separation of the globulins by dialysis.

Again, 4000 grams of straight flour were treated with 8 litres of 10 per cent. brine, allowed to subside over night, and the supernatant liquid filtered off. Another 2 litres of the brine were added to the residue, which was stirred up, allowed to settle, and again filtered. The filtrate was saturated with ammonium sulphate as rapidly as collected. The precipitate thus procured was filtered and redissolved in 10 per cent. brine. filtered clear, and dialysed until the chloride had disappeared. This resulted in the precipitation of a globulin, which was filtered off, and the solution again dialysed for 14 days, but with no further production of globulin.

The globulin-free solution was next examined by slowly heating a portion—turbidity occurred at 48°, flocks separating at 55°. After heating at 65°, the coagulum was filtered off. Further heating resulted in a minute amount of coagulum being formed at 80°: after filtering, there was no further precipitate on boiling, and nothing was obtained by adding a *little* salt and acetic acid. On adding 20 per cent. salt solution and a little acetic acid to the original solution, a precipitate was caused;

another portion was first heated to 65°, and a third to 95°, and filtered before adding the salt solution and acetic acid. The second gave less, and the third least precipitate. The filtrate from the first of these portions, when neutralised and boiled, gave no precipitate, showing that, as was to be expected, the separation of albumin by precipitation with salt and acid was complete.

This globulin-free solution gave a precipitate on saturation with sodium chloride, the filtrate became flocculent at 56°, with no further precipitate on further heating, showing that the higher coagulating protein had been thus removed. Treatment of the globulin-free solution with nitric acid yielded a precipitate, a portion of which dissolved on heating, the rest remaining insoluble: after filtration, the filtrate deposited a precipitate on cooling, which again dissolved on re-application of heat. The filtrate from the salt and acid precipitate did not give this reaction, which is characteristic of certain proteoses, and shows that the salt and acid precipitate contains a proteose, together with the albumins. Three distinct protein substances are thus recognised which are soluble in pure water; two coagulable, one at a higher temperature than the other, and presumably both albumins and a proteose.

To make sure that the body, which was apparently an albumin, was not a myosin-like globulin held in solution by the salts naturally present in river water used for dialysis, a strong aqueous solution of winter wheat meal was dialysed into distilled water in the outer vessel. The solution still coagulated at 54°, and contained in 250 c.c. only 0.0008 gram of mineral matter, proving the substance was an albumin.

218. Albumins.—The remainder of the globulin-free solution, after making the foregoing tests, was heated to 61°, the precipitate filtered, washed with water, alcohol, absolute alcohol, and ether, dried over sulphuric acid, and heated to 110°; this was called Preparation 1.

A duplicate lot was prepared in the same way, and yielded 6.4 grams from 10,000 grams of flour; this was called Preparation 2.

The filtrate from Preparation 2 was further heated to 75°, and the small amount of precipitate washed with alcohol and dried as before; this was called Preparation 3.

Another preparation was made on the same flour by extracting with 10 per cent. brine, and dialysing at once without precipitation by ammonium sulphate. After the separation of the globulins, the albumins were precipitated by at once raising the temperature to 90°; this, after drying, constituted the Preparation No. 4.

Another preparation was made on the spring wheat "shorts," by extraction with 10 per cent. salt solution, treatment with ammonium sulphate, dialysis, coagulating albumin at 65°, and drying; this was Preparation 5.

These substances gave on analysis the following results:—

Analyses of Coagulated Wheat Albumin.

	1	2	3	4	5	Average.
Carbon	53.27	53.06	—	53.02	52.71	53.02
Hydrogen	6.83	6.82	—	6.87	6.85	6.84
Nitrogen	16.95	17.01	16.94	16.26	16.83	16.80
Sulphur	1.27	1.30	—	1.20	1.34	1.28
Oxygen	21.68	21.81	—	22.65	22.27	22.06
	100.00	100.00	—	100.00	100.00	100.00

These figures agree very closely, except that the nitrogen in No. 4 is low: as four determinations give concordant results, Osborne and Voorhees consider it possible that some of the nitrogen may be lost at the higher temperature.

219. Proteoses.—As already stated, there are found in the solution after separating the globulins by dialysis, and the albumins by heating, small quantities of one or more proteoses which are almost wholly precipitated by saturation with sodium chloride. On concentrating the filtered solution, after the removal of albumins by heat, a coagulum gradually develops, which must be derived from the proteose-like protein still remaining in solution before concentration.

This body gave on analysis the following figures:

Carbon	51.86
Hydrogen	6.82
Nitrogen	17.32
Sulphur Oxygen	24.00
	100.00

The small quantity of proteose still remaining after removal of the coagulum was not separated for analysis. In analyses quoted later, paragraph 234, the amount of this proteose is seen to be as much or more than that of the coagulum.

220. Globulin.—The extraction of this body has already been referred to: in a direct experiment for the preparation of globulin, 10,000 grams of "straight" flour were extracted with 34 litres of 10 per cent. salt solution, stirred and allowed to stand over night. This was filtered, precipitated by saturation with ammonium sulphate, filtered and again dissolved in 10 per cent. brine. The solution produced was exceedingly viscid, and filtered with extreme difficulty; this was placed in a dialyser and left in a stream of running water until the chlorides were removed. The globulin gradually separated out in minute particles of spheroidal form. The precipitate was filtered, washed with water, alcohol, and ether, dried over sulphuric acid and then weighed 5.8 grams. Globulin, thus prepared, dissolves in 10 per cent. salt solution, from which it is precipitated by the addition of water. Saturation with sodium chloride gives no precipitate, but saturation with magnesium sulphate, or ammonium sulphate, completely precipitates the globulin. The solution in 10 per cent. brine gives, on slow heating, a very slight turbidity at 87°, which increases slightly up to 99°. Dried at 110°, this globulin constituted Preparation 8.

A preparation was also made in the same way, except that the precipitation with ammonium sulphate was omitted. Again the solution was remarkably viscid, a property possibly due to the presence of gum, for the pure solution of globulin in 10 per cent. brine showed no trace of it, neither did an aqueous solution of the flour. On dissolving up the globulin obtained by dialysis in 10 per cent. salt solution, a residue remains, consisting of an "albuminate" derived from the globulin. This globulin constituted Preparation 9.

The globulin was also extracted from the "shorts," and its total quantity amounted to nearly twice as much as was similarly obtained from a like quantity of flour. This globulin was Preparation 10.

The globulins gave on analysis the following results:—

ANALYSES OF WHEAT GLOBULINS.

	8	9	10	Average.
Carbon	51.07	51.01	51.00	51.03
Hydrogen	6.75	6.97	6.83	6.85
Nitrogen	18.27	18.48	18.26	18.39
Sulphur	23.91	0.71	0.66	0.69
Oxygen		22.83	23.25	23.04
	100.00	100.00	100.00	100.00

In contradistinction to the views held by Weyl and Bischoff, and Martin, Osborne and Voorhees have only found in extracts of wheat meal, either spring or winter wheat, the one globulin just described; which in properties and composition closely resembles those globulins found in other seeds.

221. Protein Soluble in Dilute Alcohol; Gliadin.—Whether wheat flour be extracted direct with dilute alcohol, or after treatment with 10 per cent. salt solution, a considerable amount of protein is obtained. The same is the case if the previously extracted gluten be subjected to alcohol extraction. Extracts were made by alcohol under all these conditions, and subjected to repeated fractional precipitations, in order to learn whether a single protein body or a mixture had been obtained.

222. Direct Alcoholic Extraction.—In direct treatment with alcohol 5000 grams of "straight" flour were extracted with 10 litres of alcohol, 0.90 specific gravity, and allowed to soak over night. The mixture was then stirred, allowed to settle, and the supernatant liquid poured off. Three litres more of alcohol of the same strength were added, and presumably stirred in; after standing, the clear liquid was poured off, and the residue put in a screw press and squeezed nearly dry. The whole of the liquid thus obtained was mixed, and constituted "Extract 1." The residue was again treated with 4 litres of 0.90 alcohol, and once more pressed nearly dry; this liquid was "Extract 2." The same process was twice more repeated, and the two extracts mixed, which gave "Extract 3." Each of the three extracts was filtered clear, and concentrated separately to one-third its volume, and after cooling decanted from the very glutinous viscid mass which had separated. This precipitated mass was in each case dissolved in a small amount of hot alcohol, sp. gr. 0.90, and the solution allowed to cool over night: most of the substance separated on cooling, and the liquid was decanted from it. The solutions were treated with a quantity of distilled water and a little sodium chloride added, the protein was thus precipitated, washed with water, absolute alcohol, and ether, and dried. The residue was subjected to a series of fractional precipitations based on the principle of partially dissolving with alcohol of 0.820 sp. gr., and precipitating from the solution by the addition of small quantities of sodium chloride solution, which precipitate was washed, dehydrated with absolute alcohol, digested with ether, and dried over sulphuric acid. A portion of the principal fraction was again divided by solution in 250 c.c. of 0.90 alcohol, and partial precipitation by pouring the solution into 800 c.c. of absolute alcohol; precipitate and solution were again treated separately. As the result of a series of fractional precipitations, altogether thirteen fractions were prepared and then analysed. These constituted Preparations 11 to 23. The results of the whole series are given by Osborne and Voorhees, but five of the fractions are discarded from the final comparison, because of their being impure, for obvious reasons. Some, for example, contain fat, while others have concentrated in them the solid matter which in a series of filtrations has passed through the filter papers. Subjoined is given the results of these various analyses, and the weight of each fraction which was obtained:—

ANALYSES OF "FRACTIONS" OF THE WHEAT PROTEIN OBTAINED BY DIRECT EXTRACTION WITH DILUTE ALCOHOL.

	15	16	17	18	19	21	24	25	26
Carbon ..	52.52	52.77	52.67	52.55	52.74	52.82	—	52.33	52.38
Hydrogen..	6.78	6.78	6.70	6.85	6.77	6.81	—	6.91	7.13
Nitrogen ..	17.64	17.77	17.66	17.94	17.62	17.67	17.69	17.70	17.82
Sulphur ..	1.08	1.26	1.22	1.21	1.23	1.11	—	23.06	22.67
Oxygen ..	21.98	21.42	21.75	21.45	21.64	21.57			
	100.00	100.00	100.00	100.00	100.00	100.00	—	100.00	100.00
Weight of fraction in grams	12.40	8.60	32.26	5.34	17.43	63.0	—	—	—

Nos. 24, 25, 26 are fractional re-precipitations of fraction No. 21.

A study of this series of analyses shows that the whole of the fractions are in remarkable agreement, and that no fractional separation of the extracted protein has been effected. For example, Nos. 15 and 16, which are aqueous solutions, have the same composition as those from solution in 0.820 alcohol, and also as the residue remaining after treatment with these reagents. Osborne and Voorhees draw the conclusion that it may be safely concluded that wheat contains but one protein soluble in dilute alcohol. The total amount of protein contained in the whole of these preparations is 207.83 grams, being equal to 4.16 per cent. of the flour.

223. Alcoholic Extraction after Salt Solution Extraction.—For this purpose 4000 grams of "straight" flour were taken, extracted with 10 per cent. salt solution so long as anything was removed, and then the residue squeezed as dry as possible in a screw-press. This residue was then treated with alcohol of such a strength as to yield with the water retained in the flour as nearly as possible a solution containing 75 per cent. of alcohol. Digestion with this solvent was continued for two days; the extract was squeezed in a press, and the process repeated three times, giving altogether four extracts. These were concentrated to small bulk, and the solution decanted from the separated mass, which was washed with distilled water, re-precipitated by sodium chloride, washed with absolute alcohol, digested with ether, and dried over sulphuric acid. The precipitates obtained from the water washings by adding salt were treated in the same way. The total weight of these preparations was 157.45 grams, equal to 3.94 per cent. of flour, as against 4.16 per cent. obtained by direct extraction, showing that the dilute alcohol extract is different and distinct from the proteins soluble in water. These constituted Preparations 27-31. The table on the following page gives the result of their analyses.

ANALYSES OF "FRACTIONS" OF WHEAT PROTEIN OBTAINED BY EXTRACTION WITH DILUTE ALCOHOL AFTER SODIUM CHLORIDE EXTRACTION.

	27	28	29	30	31
Carbon	52.69	52.72	52.71	—	52.65
Hydrogen	6.84	6.86	6.81	—	6.83
Nitrogen	17.73	17.89	17.75	17.08	17.79
Sulphur	1.02	0.95	1.10	—	1.08
Oxygen	21.72	21.58	21.63	—	21.65
	100.00	100.00	100.00	—	100.00
Weight of fraction in grams	82.0	57.0	11.3	1.35	5.8

Nos. 27-30 are the precipitates obtained from the four extracts; No. 31 is obtained from the water washings of 27 and 28.

The results of these analyses agree very closely among themselves, and also with the series obtained by direct alcoholic extraction.

224. Extraction of Gluten with Dilute Alcohol.—For the preparation of gluten, 2000 grams of "straight" flour were made into dough with distilled water at 20°, and then washed in a stream of river water at 5° C. When nearly the whole of the starch had thus been removed, the gluten was chopped fine and digested with alcohol of 0.90 sp. gr. at a temperature of about 20°. This extraction was repeated with fresh portions of alcohol of the same strength so long as anything was removed. The extracts were united, filtered clear, and evaporated down to one-fourth their original volume. This was allowed to stand over night, and the supernatant liquid decanted from the separated protein. This latter was then dehydrated with absolute alcohol. The original mother-liquor from which the protein had separated, and also the absolute alcohol used for dehydrating, were each precipitated by a small quantity of sodium-chloride solution. The three products were united, digested with absolute alcohol, and then with absolute ether. After drying over sulphuric acid, the Preparation No. 32 weighed 82.0 grams, and formed 4.10 per cent. of the flour taken. In order to determine whether this substance was a single protein or a mixture of more than one, the process of fractional precipitation was again employed. Thirty grams of Preparation 32 were dissolved in 0.90 alcohol, concentrated to small volume, and then strong alcohol added till about half the substance taken had been precipitated. The precipitate was treated with absolute alcohol, dried over sulphuric acid, and found to weigh 12 grams; this constituted Preparation 33. The solution was precipitated with water, dehydrated and dried over sulphuric acid; it weighed 16 grams, and was marked Preparation 34. These substances had the following composition:—

ANALYSES OF "FRACTIONS" OF THE WHEAT PROTEIN OBTAINED BY EXTRACTION OF GLUTEN WITH DILUTE ALCOHOL.

	32	33	34
Carbon	52.58	52.68	52.84
Hydrogen	6.67	6.78	7.18
Nitrogen	17.65	17.65	17.57
Sulphur	1.08	1.09	22.41
Oxygen	22.02	21.80	
	100.00	100.00	100.00

In this case also the analyses show clearly that no separation into proteins of differing composition had thus been effected.

225. Extraction of "Shorts" with Dilute Alcohol.—In order to determine whether the "shorts" or bran flour yielded the same body to dilute alcohol, 2000 grams were taken and subjected to much the same process of extraction as was flour, except that greater precautions were necessary in order to remove impurities. Two Preparations, Nos. 36 and 37, were obtained, which had the following composition:—

ANALYSES OF FRACTIONS OF WHEAT PROTEIN OBTAINED BY EXTRACTION OF "SHORTS" WITH DILUTE ALCOHOL.

	36	37
Carbon	52.85	52.74
Hydrogen	6.81	6.87
Nitrogen	17.48	17.67
Sulphur Oxygen	22.86	22.72
	100.00	100.00

A comparison of these figures with those which have preceded shows that the protein extracted from the bran has a similar composition to that obtained from the flour.

226. Extraction of Whole Wheat Meal with Dilute Alcohol.—In view of the fact that Ritthausen, and probably others, employed whole wheat meal in their investigations of the composition of wheat proteins, Osborne and Voorhees decided to make some experiments on wheat meals, in addition to those previously described. Accordingly, 1000 grams of freshly ground whole spring wheat meal were taken, made into a dough, and the gluten extracted. This was chopped fine, thoroughly extracted with 0.90 alcohol, the extract concentrated, and the protein separated by cooling. This deposit was dissolved as far as possible in dilute alcohol, and the insoluble substance washed with absolute alcohol, and ether, and dried over sulphuric acid. This was Preparation 38. The solution was precipitated with absolute alcohol, dried as usual, and constituted Preparation 39; the filtrate from this was concentrated to small volume, poured into absolute alcohol, and the precipitate washed and dried as before, giving Preparation 40.

In a similar manner, Preparations were made from winter wheat meal; the coagulated protein was labelled 41, and that obtained by further digestion, 42. These had the following composition:—

ANALYSES OF WHEAT PROTEINS OBTAINED BY EXTRACTION OF WHOLE WHEAT MEAL WITH DILUTE ALCOHOL.

	Spring Wheat.			Winter Wheat.	
	38	39	40	41	42
Carbon	52.90	52.89	53.16	52.82	52.68
Hydrogen	6.99	6.87	6.83	6.88	6.81
Nitrogen	17.52	18.06	17.75	17.55	17.63
Sulphur	1.43	0.92	0.96	22.75	22.88
Oxygen	21.16	21.26	21.30		
	100.00	100.00	100.00	100.00	100.00

Throughout the whole series there is no essential difference in composition, nor in physical properties; nor was the protein altered in composition by solution in dilute caustic potash, and re-precipitation by an equivalent quantity of hydrochloric acid; neither, so far as it could be observed, was its solubility altered.

The composition of this protein, as obtained by averaging the preceding figures, is the following:—

Carbon	52.72
Hydrogen	6.86
Nitrogen	17.66
Sulphur	1.14
Oxygen	21.62
	100.00

227. Properties of Protein extracted by Dilute Alcohol.—If this protein be dehydrated by absolute alcohol, and thoroughly dried over sulphuric acid, it forms a snow-white friable mass easily reduced to powder. When dried from weak alcohol or water, it forms an amorphous transparent substance, closely resembling pure gelatin in appearance, being, however, rather more brittle than that body. In the cold, distilled water turns the substance sticky, and a part dissolves. As the water is warmed, the degree of solubility increases, and with boiling, a considerable quantity goes into solution. A portion of this is re-deposited on cooling. **The solution in pure water is instantly precipitated by adding a very minute amount of sodium chloride.** In absolute alcohol this protein is perfectly insoluble, but dissolves on the addition of water, being very soluble in 70 to 75 per cent. alcohol. From alcoholic solutions, minute quantities of salt readily precipitate the protein. Exceedingly dilute acids and alkalies readily dissolve this protein, which is again precipitated apparently unchanged in appearance and composition by neutralisation.

This protein has been obtained in a more or less pure form by earlier observers; Taddei first gave it the name of "gliadin." Ritthausen and others assumed that it consisted of a mixture of two or more substances, to which the names of mucin or mucedin, and gliadin or vegetable gelatin, have been given. Among recent observers, Martin found in gluten only one protein soluble in dilute alcohol, to which he gave the name of "insoluble phyt-albumose," but, curiously enough, stated that flour extracted direct with 76 to 80 per cent. alcohol yielded no soluble protein. This is in direct opposition to the results of Osborne and Voorhees, and also, it may be added, to those of the authors of the present work, one of whom, prior to seeing Osborne and Voorhees' paper, made a series of analyses of various flours, in which a direct gliadin estimation by alcohol was included. Osborne and Voorhees adopt **gliadin as the original and appropriate name for the wheat protein soluble in dilute alcohol.** They point out that gliadin is absolutely distinct in properties and composition from the other alcohol-soluble proteins, prolamins, obtained from the kernel of oats and maize.

228. Protein insoluble in Water, Saline Solutions, and Alcohol; Glutenin.—After treatment with the series of previously described solvents, a protein body remains in wheat flour and gluten, which is soluble only in dilute acids and alkalies. **This protein being especially characteristic of gluten, Osborne and Voorhees have given it the name Glutenin.**

In the following accounts of extraction of glutenin, it is throughout understood that the separations are made on flour or meal which has previously been exhausted with one or more of the following solvents: Water, 10 per cent. salt solution, and dilute alcohol.

229. Extraction of Glutenin from "Straight" Flour after Treatment with Brine and Dilute Alcohol.—After completely exhausting 4000 grams of straight flour successively with 10 per cent. brine and 0.90 sp. gr. alcohol, the residue was extracted twice with 0.1 per cent. potash solution. The residual protein was soluble in this, and after standing three days at a temperature of 5°, with frequent stirring, the extract was filtered off and allowed to stand in a cold room until most of the finer solid impurities had subsided. The still turbid solution was then decanted and neutralised with 0.2 per cent. hydrochloric acid, thereby producing a precipitate which subsided rapidly, leaving a milky filtrate. This precipitate was redissolved in the dilute potash, allowed to stand in order to deposit impurities, and again precipitated with 0.2 per cent. hydrochloric acid. The protein was washed with water, dilute alcohol, absolute alcohol, and ether. This preparation was found to be far from pure, and accordingly a portion of it was again dissolved in 0.2 per cent. potash, and repeatedly filtered through very dense filter paper till perfectly clear. As this filtration proceeded very slowly the operation was conducted in a refrigerator at a temperature near 0° C. Two successive portions of the filtrate obtained were reprecipitated with 0.2 per cent. hydrochloric acid, washed with water, alcohol, ether, and dried over sulphuric acid, and then at 110°. These gave Preparations 45 and 46. It was found absolutely necessary to filter the potash solution *perfectly clear,* as otherwise considerable amounts of non-nitrogenous matter are subsequently carried down with the precipitate.

230. Extraction of Glutenin after Treatment of Dough with Water and Exhaustion with Dilute Alcohol.—A dough was made with 2000 grams of spring wheat "straight" flour and distilled water; this was washed with river water till freed so far as possible from starch. The gluten was exhausted with 75 per cent. alcohol, and the insoluble residue dissolved in 0.15 per cent. potash solution, and allowed to stand in a cold room for 48 hours. The solution was decanted, precipitated with dilute hydrochloric acid, washed thoroughly with water, absolute alcohol, and ether. It was then again dissolved in 0.1 per cent. potash, allowed to stand over night, filtered till perfectly clear, and a part of the filtrate precipitated by neutralising with 0.2 per cent. hydrochloric acid. This precipitate was dried as usual, and constituted Preparation 48.

Another lot of gluten was prepared in the same way from 1000 grams of "straight" flour, extracted with alcohol and then dissolved in potash water. After standing, this was precipitated by adding acetic acid to slightly acid reaction. The precipitate was washed with water, alcohol, and ether, and again dissolved in potash water, reprecipitated with hydrochloric acid, and again washed and dried as usual over sulphuric acid. A pure white light mass was obtained, which was marked Preparation 51.

In order to determine whether the protein lost any nitrogen by prolonged solution in potash water, another lot of gluten was similarly treated, and the potash solution kept in an ice-chest for 20 hours, and then precipitated and treated in the usual manner. This constituted Preparation 52, and had evidently lost but exceedingly little nitrogen.

231. Extraction of Glutenin after Direct Exhaustion of Flour with Alcohol, Water Treatment Omitted.—Another preparation was made by extracting 200 grams of spring patent flour with large quantities of alcohol of 0.90 sp. gr., then washing the flour with absolute alcohol and drying and air-drying. The dry flour was then made into a dough, which possessed considerable coherence, showing that the protein insoluble in alcohol has an important function in dough production. The dough was washed on a hair-sieve under a stream of water, but yielded no coherent gluten. The washings were allowed to settle, and the sediment treated with 0.2 per cent. potash. After standing, the supernatant liquid was decanted, precipitated with dilute hydrochloric acid, and the precipitate allowed to settle. It was then again dissolved in dilute potash, filtered perfectly clear while in the ice-chest, reprecipitated, and washed and dried in the usual manner. This constituted Preparation 56.

Another experiment was made by direct alcohol treatment, in which 1000 grams of "straight" flour were exhausted with 0.90 alcohol, and the residue squeezed in a screw-press. This was then extracted with 0.2 per cent. potash, but filtration was impossible owing to the gummy nature of the liquid. An equal volume of alcohol, sp. gr. 0.820, was then added, and after long standing a comparatively clear yellow solution was syphoned off and filtered clear. This was precipitated with hydrochloric acid, and the precipitate filtered off and again dissolved in potash, filtered perfectly clear, reprecipitated, washed with water, dilute and then absolute alcohol, and ether. This yielded Preparation 57, the analysis of which shows that the same protein is extracted by potash water from the flour which has not been in contact with water as was obtained in other experiments.

232. Extraction of Glutenin from Gluten of Whole Wheat Flour.—A dough was made from 1000 grams of whole spring wheat meal, washed till free from starch, and the gluten exhausted with dilute alcohol. The residue was dissolved in dilute potash, allowed to stand, decanted, reprecipitated, and the precipitate washed with water, dilute alcohol, absolute alcohol, and ether, and then re-dissolved in 0.2 per cent. potash water. This was filtered perfectly clear, and precipitated and treated in the usual way. The dry protein was Preparation 58.

A preparation was made in the same manner from whole winter wheat meal, which constituted Preparation 60. In the following table, analyses are given of the whole of the glutenin preparations which have been described.

Analyses of Protein of Wheat Soluble only in Dilute Acids and Alkalies—Glutenin.

	45	46	48	51	52	56	57	58	60
Carbon	52.29	—	52.32	52.54	52.38	—	52.19	52.19	52.03
Hydrogen	6.61	—	6.82	6.85	6.81	—	6.92	6.93	6.83
Nitrogen	17.41	17.33	17.61	17.46	17.59	17.20	17.56	17.45	17.48
Sulphur	0.94	—	23.25	1.07	1.24	—	23.33	23.43	23.66
Oxygen	22.75	—		22.08	21.98	—			
	100.00	—	100.00	100.00	100.00	—	100.00	100.00	100.00

233. Properties of Glutenin.—The characteristic reactions of glutenin, owing to its comparative insolubility, are not numerous. A minute quantity is dissolved by cold water, and more on slightly warming. Diluted alcohol also dissolves a small quantity of protein in the cold, and a larger quantity on boiling, which again precipitates as the liquid cools. It is just possible that this is due to the presence of traces of gliadin, but in face of the very careful exhaustion by alcohol previous to preparation of glutenin, it is more probable that glutenin itself is slightly soluble both in warm alcohol and warm water.

When freshly precipitated and hydrated, glutenin is soluble in 0.1 per cent. potash solution, and 0.2 per cent. hydrochloric acid. In this condition it is also soluble in the slightest excess of sodium carbonate solution or ammonia. After drying over sulphuric acid, it becomes rather less soluble in all these reagents. On comparing the analyses of gliadin and glutenin, a very close agreement is observed. It is well known that many proteins pass readily into conditions in which their solubility is changed without any alteration in their composition, capable of detection by analysis. Osborne and Voorhees therefore concluded that gluten was made up of two forms of the same protein, one being soluble in cold dilute alcohol, and the other not soluble. But Osborne, who has since studied the products of their complete hydrolysis, finds that gliadin differs sharply from glutenin in yielding no glycine and no lysine; it also gives nearly twice as much proline as glutenin (*Armstrong, Supplement, Jour. Board of Agric., June,* 1910, p. 48). It can scarcely, therefore, be maintained that these proteins have a common origin.

234. Amount of the various Proteins contained in Wheat.—The percentage of each protein present in whole-wheat meal was determined by an analysis of 1000 grams of meal from spring and winter wheats respectively. The following is an outline of the analytic method adopted, which was the same in each case. To 1000 grams of fine meal were added 4000 c.c. of 10 per cent. salt solution, and the extract filtered; 2500 c.c. of clear extract were obtained from the spring meal, and 2600 from the winter wheat meal. As 100 c.c. of solution were used to each 25 grams of flour,

2500 c.c. = extract from 625 grams spring meal, and
2600 c.c. = „ „ 650 „ winter meal.

The extracts were dialysed for five days, at the end of which time they were free from chloride. The precipitated globulin was filtered, washed with distilled water, alcohol, absolute alcohol, and ether, and dried at 110°. The following weights were obtained:—

3.8398 grams = 0.624 per cent. globulin in spring wheat.
3.9265 „ = 0:625 „ „ „ winter „

The filtrates from the globulin were heated to 65°, and the coagula formed at that temperature removed by filtration, washed as usual, dried at 110°, and weighed with the following results:—

1.9714 grams = 0.315 per cent. No. 1 albumin in spring wheat.
1.9614 „ = 0.302 „ „ „ winter „

The filtrates from these were heated to boiling, and the second coagula similarly treated. The weights obtained were:—

0.4743 grams = 0.076 per cent. No. 2 albumin in spring wheat.
0.3680 „ = 0.057 „ „ „ winter „

The filtrates were evaporated nearly to dryness, and two crops of coagulated protein removed, washed, dried, and weighed—together they amounted to:—

1.6886 grams = 0.269 per cent. coagulum in spring wheat.
1.4516 „ = 0.223 „ „ „ winter „

The filtrates from the coagula were next again evaporated to a syrup and, as no insoluble matter separated, were precipitated by pouring into strong alcohol, the precipitates were washed, dissolved in water and reprecipitated, washed with absolute alcohol and ether, and dried at 110°. They were evidently very impure, and the amount of protein present in each was estimated by determining the nitrogen and multiplying by 6.25. They gave in this way the following results:—

1.3297 grams = 0.213 per cent. proteose and peptone in spring wheat.
2.8063 „ = 0.432 „ „ „ „ winter „

Collecting these figures, the sodium-chloride solution contained the following amounts of protein matter:—

	Spring Wheat.	Winter Wheat.
Globulin	0.624 per cent.	0.625 per cent.
Two Albumins together	0.391 „	0.359 „
Coagulum	0.269 „	0.223 „
Proteose	0.213 „	0.432 „
Total	1.497 „	1.639 „

The remainder of the protein matter constitutes the gluten, and was determined in the following manner—200 grams of each meal were made into a dough and washed free from starch. The wet gluten, freed from adhering moisture, was then weighed, and exactly one-half dried at 110° to constant weight.

Spring wheat yielded 12.685 per cent. dry gluten.
Winter „ „ 11.858 „ „ „

The other half of the gluten was cut up fine, and extracted with alcohol of 0.90 sp. gr. The extract was concentrated, and the precipitated protein extracted with ether and dried at 110°. Reckoned on the whole meal,

Spring wheat gluten yielded 4.3379 per cent. gliadin.
Winter „ „ 4.2454 „ „

The residues, after exhaustion with alcohol, were then dried at 110° and weighed. Reckoned on the whole meal,

Spring wheat gluten yielded 7.800 per cent. matter insoluble in alcohol.
Winter „ „ „ 7.504 „ „ „ „

Nitrogen determinations were then made on the following bodies—the whole meal insoluble alcohol residues, dried gluten, and the sediments of the water used for washing out gluten, after being washed with strong alcohol, dried and weighed. The following is the tabulated result of the various determinations:—

Proximate Analyses of Proteins of Wheat.

	Spring Wheat.	Winter Wheat.
Total nitrogen in the meal	1.950 per cent.	1,940 per cent.
Total gluten in the meal	12.685 „	11.858 „
Part of gluten insoluble in alcohol	7.800 „	7.504 „
Per cent. of nitrogen in gluten	12.010 „	12.000 „
Total nitrogen in gluten in per cent. of flour	1.5222 „	1.4230 „
Total nitrogen in residue of gluten insoluble in alcohol	0.8245 „	0.7346 „
Total nitrogen extracted by alcohol	0.6977 „	0.6884 „
Gliadin (N$\times$5.68, assuming 17.60 per cent. of N in gliadin)	3.9630 „	3.9100 „
Gliadin by direct weighing	4.3379 „	4.2454 „
Nitrogen in sediment from washing gluten	0.2239 „	0.1552 „

	Spring Wheat.		Winter Wheat.	
	Nitrogen.	Protein.	Nitrogen.	Protein.
Glutenin	0.8245×5.68=	4.683	0.7346×5.68=	4.173
Gliadin	0.6977×5.68=	3.963	0.6884×5.68=	3.910
Globulin	0.1148	= 0.624	0.1148	= 0.625
Albumin	0.6057	= 0.391	0.0603	= 0.359
Coagulum	0.0453	= 0.269	0.0379	= 0.223
Proteose	0.0341	= 0.213	0.0791	= 0.432
From Water Washings of Gluten ..	0.2239×5.68=	1.272	0.1552×5.68=	0.881
Total	2.0050	11.415	1.8703	10.603
Meal	2.10 ×5.68=	11.93	1.94 ×5.68=	10.96

Inspection of the above figures shows that the gliadin by direct weighing agrees fairly well with that estimated from a nitrogen determination. The residue insoluble in alcohol is, however, very much more than the true glutenin: thus, in the spring wheat the insoluble residue weighed 7.80 per cent. of the meal, whereas the glutenin calculated from nitrogen amounted to only 4.683, leaving 3.117 of foreign matter in the residue insoluble in alcohol. The total protein agrees in each case very closely with the whole found by direct estimation on the meal. The same figures as those above given are quoted in a work recently written by Osborne (1909) as representing the amounts of proteins contained in the grain of wheat.

235. The Formation of Gluten.—So far as is known, wheat is the only plant whose seeds contain proteins in such a form as to enable them to be separated in a coherent mass from the other constituents by washing with water. Osborne and Voorhees have examined very carefully the views promulgated on this point by previous observers; prominent among these is the "ferment" hypothesis of Weyl and Bischoff, who, as previously stated, considered the proteins of wheat meal to consist principally of a globulin very similar in character to myosin, and which they therefore termed "vegetable myosin." This they regarded as the mother-substance of gluten, which on the addition of water is changed by a ferment, hitherto unisolated, into gluten, "as other proteins, if present at all, exist only in small amount" (Weyl and Bischoff). The exhaustive analyses previously quoted show that globulin and also gliadin form only about half the total protein of the grain. Osborne and Voorhees point out that gliadin is extracted in similar quantity from dry flour direct by alcohol, as is yielded after treatment with 10 per cent. sodium chloride solution, or by direct extraction of the previously washed out gluten. Weyl and Bischoff state that with the aid of a 15 per cent. salt solution the flour was extracted till no protein could be detected in the extract; the residue of the meal kneaded with water then gave no gluten. *"If the globulin substance is extracted, no formation of gluten takes place."* Osborne and Voorhees confirm this if the flour is stirred up with a large quantity of salt solution, and then extracted repeatedly with fresh quantities of the solution. But they say: "If, however, wheat flour is mixed at first with just sufficient salt solution to make a firm dough, this dough may then be washed indefinitely with salt solution, and will yield gluten as well and as much as if washed with water alone."

This statement alone is scarcely a sufficient disproof of Weyl and Bischoff's position. In a firm dough made with 15 per cent. salt solution, the quantity of salt will only amount to 5 per cent. of the dough. As nothing has been removed in the act of making dough, it may be reasonably claimed that this quantity of salt is insufficient to prevent the ferment performing its function, and thus producing gluten; while further, the gluten once formed is able to withstand the action of the salt solution which is unable to decompose it. Osborne and Voorhees go on to state that "when large quantities of salt solution are applied at once, the flour fails to unite to a coherent mass, and cannot afterwards be brought together." This action of salt solution in large quantities is explained by subsequent experiments, in which it is shown that such solution materially modifies the adhesive nature of gliadin.

Weyl and Bischoff's experiment, in which they extracted the flour with 90 per cent. alcohol, is scarcely conclusive, because according to both hypotheses this would result in the non-formation of gluten. In the one case globulin would be coagulated, and in the other gliadin would be removed, and so according to both reasoners no gluten could be produced.

More recently, Martin has advanced a somewhat similar theory of gluten formation; he finds one protein in gluten soluble in alcohol, and in hot water, but not in cold, which protein he calls an insoluble phyt-albumose. The gluten is termed by him "gluten-fibrin." Martin next inquires: Does flour contain gluten-fibrin? Does it contain insoluble phyt-albumose? He states that the first question cannot be answered directly, and that, if phyt-albumose originally existed in the flour, it should be extracted by 76-80 per cent. alcohol, which, however, extracts only fat. There is here direct conflict of experimental evidence, as the analyses previously quoted show that considerable quantities of a protein are thus extracted. Martin next points out that 10 per cent. sodium chloride solution extracts a large quantity of globulin of the myosin type and of albumose. Osborne and Voorhees consider that Martin has made the mistake of taking albumin for a myosin-like globulin, and, owing to the voluminous nature of the body when coagulated, has been misled as to its amount. Martin further looks upon the insoluble albumose as formed from the soluble, and that the globulin is transformed into gluten-fibrin. That a body should be obtained from a solution of globulin, which gave the same reactions as gluten-fibrin, is not surprising, as so-called albuminates, having no characteristic reactions, are derived from nearly all globulins. Martin tabulates his theory as follows:—

$$\text{GLUTEN}=\begin{cases}\text{Gluten-fibrin} & \text{—precursor,} & \text{globulin.}\\ \text{Insoluble albumose—} & \text{,,} & \text{soluble albumose.}\end{cases}$$

Osborne and Voorhees cannot admit this theory, because it is founded on two erroneous observations: 1st, that 80 per cent. alcohol does not extract protein from flour; 2nd, that at least one-half the protein of the seed is a myosin-like globulin.

Osborne and Voorhees conclude that no ferment action is involved in the formation of gluten, and that it contains but two protein substances, glutenin and gliadin, and that these exist in the wheat kernel in the same form as in the gluten, except that in the latter they are combined with about thrice their weight of water. This opinion is based on the following reasons:—

1. Alcohol extracts the same gliadin in the same amount, whether applied directly to the flour, to the gluten, or to the flour previously extracted with 10 per cent. sodium chloride solution.

2. Dilute potash solution extracts glutenin of uniform composition and properties from flour which has been extracted with alcohol, or with 10 per cent. sodium chloride solution and then with alcohol, as it extracts from gluten which has been exhausted with alcohol.

Viewed as a refutation of the ferment theory, the weak point of this statement is that in order to prepare gliadin the flour is in all cases treated with water, as even the alcohol used contains water to the extent of 30 per cent. (although extraction with 70 per cent. alcohol is a condition the reverse of favourable to ferment action). The advocates of the ferment theory might adduce the fact that small quantities of ferment substance are capable of changing very large quantities of the body on which they act, and further might suggest that the small quantity of globulin which is removed by treatment with sodium chloride solution is the ferment in question. It is well known that flour contains a diastase precipitated by alcohol, which presumably belongs to the albumins or globulins; it is therefore conceivable that among the globulin, albumin, and indefinite proteoses of wheat, a ferment may exist capable in the presence of water of producing gliadin from some other pre-existing substance. It is difficult, however, to prove a negative, and the onus of proving the existence of ferment action lies rather with those who are advocates of that hypothesis than with those who view it as unnecessary. Osborne and Voorhees, without actually absolutely disproving the existence of a gluten-ferment, account rationally and scientifically for the production of gluten on the assumption of the pre-existence of its constituents as such in the grain; the balance of evidence is strongly in favour of the latter hypothesis.

The following experiments are adduced to show that both glutenin and gliadin are necessary for the production of gluten. A portion of flour was washed free from gliadin by alcohol of 0.90 sp. gr., and next with stronger alcohol, and finally with absolute alcohol, and air dried. The residue made a tolerably coherent dough, but much less tough and elastic than that obtained from the untreated flour. On washing this dough most carefully, not a trace of gluten could be obtained.

In another experiment 7.5 grams of finely ground air-dried gliadin were mixed with 70 grams of starch, and distilled water added. A plastic dough was formed, but it had no toughness. On adding a little 10 per cent. sodium chloride solution the dough became tough and elastic. This was washed with great care with cold water, a little salt solution being added from time to time; no gluten was, however, obtained.

The following experiment shows that additional gluten is formed when glutenin is present, by the adding of gliadin. Two portions of 100 grams each of flour were taken, and to one of them 5 grams of gliadin added. Both were made into dough with the same quantity of water. The two doughs exhibited considerable differences, that containing the extra gliadin being the yellower and tougher of the two. Gluten was extracted from each by washing, after which each was weighed in the wet condition; that containing the added gliadin weighed 44.55 grams, and the other 27.65 grams. On drying at 110° the yield of dry gluten was respectively 15.41 grams and 9.56 grams; the difference being 5.85 grams, which amount more than covers the added gliadin.

On heating finely ground air-dried gliadin with a small quantity of distilled water, a sticky mass is formed which, on the addition of more distilled water, forms a turbid solution. But, if to the gliadin moistened with distilled water a very dilute solution of salt in distilled water is added, the gliadin is changed into a very coherent viscid mass which adheres to everything it touches, and can be drawn out into long threads. Treatment of gliadin with 10 per cent. salt solution, first to moisten it, and afterward in larger quantity, serves to cause the substance to unite in a plastic mass which can be drawn out into sheets and strings, but is not adhesive. This explains the non-success of Weyl and Bischoff's experiment before referred to. The gliadin is the binding material which causes the particles of flour to adhere together, thus forming a dough. But the gliadin alone is not sufficient to form gluten, for it yields a soft and fluid mass which breaks up entirely on washing with water. The insoluble glutenin is probably essential as affording a nucleus to which the gliadin adheres, and from which it is not mechanically carried away by the wash water.

236. Summary.—The following are the properties and composition of the proteins of the wheat grain:—

1. A *globulin,* soluble in saline solutions, precipitated therefrom by dilution, and also by saturation with magnesium sulphate or ammonium sulphate, but not by saturation with sodium chloride. Partly precipitated by boiling, but not coagulated at temperatures below 100°. The grain contains between 0.6 and 0.7 per cent. of globulin.

2. An *albumin,* coagulating at 52°, which differs from animal albumin in being precipitated on saturating its solutions with sodium chloride, or with magnesium sulphate, but not precipitated by completely removing salts by dialysis in distilled water. The grain contains between 0.3 and 0.4 per cent. of albumin.

3. A *proteose,* precipitated (after removing globulin by dialysis, and the albumin by coagulation) by saturating the solution with sodium chloride, or by adding 20 per cent. of sodium chloride and acidulating with acetic acid. Separates as a coagulum on concentrating the solution, and thus yields about 0.3 per cent. of the grain.

The solution from this coagulum still contained a proteose-like body which was not obtainable in a pure state. By indirect methods it is assumed to amount to from 0.2 to 0.4 per cent. of the grain. Both these substances, the coagulum and the proteose-like body, are derivatives of some other protein in the seed, presumably the proteose first mentioned. As previously explained, it should be borne in mind that the proteoses may be formed during the processes of extraction by alterations of the protein matter originally present in the grain.

4. *Gliadin,* soluble in dilute alcohol, and soluble in distilled water to opalescent solutions, which are precipitated by adding a little sodium chloride. Completely insoluble in absolute alcohol, but slightly soluble in 90 per cent. alcohol, and very soluble in 70-80 per cent. alcohol, and is precipitated from these solutions on adding either much water or strong alcohol, especially in the presence of much salts; soluble in very dilute acids and alkalies, precipitated from these solutions by neutralisation, unchanged in properties and composition. The formation of gluten is largely dependent on this protein. The grain contains about 4.25 per cent. of gliadin.

5. *Glutenin,* a protein insoluble in water, saline solutions, and dilute alcohol, which forms the remainder of the proteins of the grain. Soluble in dilute acids and alkalies, and re-precipitated from such solutions by neutralisation.

The following is the composition of these bodies:—

ANALYSES OF PROTEINS OF WHEAT.

	Globulin.	Albumin.	Coagulum.	Gliadin.	Glutenin.
Carbon	51.03	53.02	51.86	52.72	52.34
Hydrogen	6.85	6.84	6.82	6.86	6.83
Nitrogen	18.39	16.80	17.32	17.66	17.49
Sulphur	0.69	1.28	24.00	1.14	1.08
Oxygen	23.04	22.06		21.62	22.26
	100.00	100.00	100.00	100.00	100.00

Wheat gluten is composed of gliadin and glutenin, both being necessary for its formation. Gliadin forms with water a sticky medium which, by the presence of salts, is prevented from becoming wholly soluble. This medium binds together the particles of flour, rendering the dough and gluten tough and coherent. Glutenin imparts solidity to the gluten, and forms the nucleus to which gliadin so adheres that it cannot be washed away with water. Gliadin and starch form a dough which yields no gluten, as the gliadin is washed away with the starch. Flour freed from gliadin gives no gluten, as there is no binding material to hold the particles together so that they be brought into a coherent mass.

Soluble salts are also necessary in forming gluten, as in distilled water gliadin is readily soluble. The mineral constituents of the flour are sufficient for this purpose, as gluten can be obtained by washing a dough in distilled water.

No ferment action occurs in the formation of gluten, for its constituents are found in the flour having the same composition and properties as in the gluten, even under those conditions which would be supposed to completely remove antecedent proteins, or to prevent ferment-action. All the phenomena which have been attributed to ferment-action are explained by the properties of the proteins themselves, as they exist in the seed and in the gluten.

The conclusions of Osborne and Voorhees agree well with the following opinions on a gluten-ferment expressed by one of the present authors in a previous work on this subject:—"The existence of this body cannot as yet, however, be recognised as proved. While the formation of gluten may be due to the intervention of such a body, yet there is nothing remarkable in considering it to be a simple and direct hydration, by water, of the gluten compounds existent in the grain. The effect of heating the flour, and of treatment with salt solution, are fairly accounted for by their well-known coagulating action on the albuminous matters. So, too, those wheats whose flours hydrate slowly are grown under conditions which favour the proteins being in a difficultly soluble condition."

237. Proteins of the Oat-Kernel.—For purposes of comparison the following statement by Osborne of the composition of the proteins of oats is given. When oat-meal is extracted with 10 per cent. sodium chloride solution, two portions of uncoagulated protein were obtained; after which alcohol extracted another uncoagulated protein. Two distinct proteins are thus obtained from oats—that extracted from untreated oats readily coagulates and becomes insoluble in alcohol, and when wet with absolute alcohol does not absorb moisture from the air; whilst that obtained from oats after treatment with salt solution has no tendency to coagulate, is freely soluble in cold alcohol of 0.90 sp. gr., and when wet with absolute alcohol absorbs moisture from the air and becomes gummy. Both substances, when washed with absolute alcohol and dried, are light yellowish powders, soluble in dilute acids and alkalies, and reprecipitated on neutralising their solutions (*American Chemical Journal*).

238. Distribution of Proteins in Wheat.—The proteins of wheat are not distributed equally throughout the whole seed, there being certain portions of the wheat grain which are specially rich in soluble proteins; the bran and germ are particularly so. Starting from the outside of the seed, the interior portions become less and less nitrogenous, until the kernel of the grain is found to consist much more largely of starch.

239. Decomposition of Proteins.—Soluble albumin, or the white of egg, on being allowed to stand, putrefies, with the evolution of sulphuretted hydrogen and other gases. The odour of sulphuretted hydrogen is almost invariably described by comparison to that of rotten eggs. Coagulated albumin, when dry, is a fairly stable body; but, when left in contact with water, putrefies, yielding valeric and butyric acids, together with other bodies. The oxygen of the air has no action on albumin.

Dry gluten may be kept indefinitely without change, but if when wet it is exposed, in masses too large to dry quickly, to air at ordinary temperatures, it gives off a quantity of gas, and at last evolves a strong putrescent odour. At the same time, the insoluble gluten breaks down into a thick creamy mass.

240. Nature of Putrefaction.—It is necessary to get accurate ideas of what putrefaction really is. Every one knows the results of putrefaction in their last or extreme stages; animal and vegetable substances both give off gases having most disgusting odours and yield a variety of offensive products. These gases consist of compounds of hydrogen with carbon, and also with sulphur; this latter gas, termed by the chemist sulphuretted hydrogen, is, as just stated, responsible for the odour so characteristic of rotten eggs. In the earlier stages, however, of putrefaction, the changes do not result in the production of such disagreeable bodies; gases are evolved, but these are either inodorous or at most possess only slight smells. Speaking broadly, putrefaction consists of the breaking down or degrading of the complex molecules of animal and vegetable structures into compounds of a more simple character, and ultimately into inorganic compounds, such as carbon dioxide, water, and sulphuretted hydrogen; which latter, in its turn, deposits its sulphur, and forms water by the action of atmospheric oxygen. Bodies in the first stage of putrefying absorb more or less oxygen: when this element has been removed from the supernatant air, a species of fermentation, known as putrefactive fermentation, proceeds. When dealing with the whole question of fermentation this change must be viewed more closely. At present there is one particular point that should, however, be mentioned, and that is, that by heating any organic liquid, as a solution of hay, white of egg, or proteins of flour, under pressure at a temperature of about 266° F. for some time, and then boiling the liquid in a flask whose neck is loosely plugged with cotton wool until the whole of the air is expelled, the liquid acquires the property of resisting putrefactive action. Solutions preserved in this manner may be kept for an indefinite length of time; on being once more exposed to the air they again are subject to putrefaction. It would thus appear that putrefaction is not a process appertaining exclusively to the grain itself, but is in some way dependent on the action and presence of air.

EXPERIMENTAL WORK.

241. Reactions of Proteins.—Separate a little gluten from flour by kneading dough, enclosed in muslin, in water. Dry a little of this, and heat strongly in a test-tube; notice that an odour is evolved similar to that of burning hair or feathers. Water also condenses in the cooler parts of the tube: test this water with a strip of red litmus paper, and notice that it has an alkaline reaction; this alkalinity is caused by the presence of ammonia. Make a precisely similar experiment with some white of egg, and observe that the same reactions occur.

Solubility.—Mix some white of egg with about four times its volume of water. Place a portion of this solution in a test-tube, float it in a beaker of cold water, and heat gently. Test the temperature at which coagulation ensues. To successive portions of the albumin solution, add alcohol, ether, mercuric chloride, and picric acid solutions, and dilute nitric acid; notice the formation of a precipitate. To the portions precipitated by acid, add caustic soda or potash solution: the precipitates are re-dissolved.

Colour Reactions.—Test the Xanthoproteic and Millon's colour reactions, as described in paragraph 204.

Precipitation.—Precipitate proteins from solutions by the various methods given in paragraph 205.

Production of Peptones.—Take some of the white of a hard-boiled egg, and rub it through a fine sieve. Add to it some dilute hydrochloric acid (0.2 per cent.) and a little prepared pepsin. Gently warm the whole to a temperature of about 40° C. and notice that the white of egg dissolves. The albumin has then been converted into peptone.

Soluble Flour Proteins.—Weigh out 50 grams of flour, and mix with 250 c.c. of water in a large flask, shake up thoroughly several times during half an hour, and then set aside for a few hours, or even over-night. Filter the supernatant liquid through a French filter paper until bright. Heat a portion of this solution in a small beaker placed in a water-bath: notice the coagulation of vegetable albumin.

242. Gluten and its Constituents.—The separation of gluten will have been illustrated in the preceding experiments. Moisten flour with alcohol and fold up in muslin; knead in a small vessel also containing alcohol; notice that no gluten is yielded. Make a similar experiment with a 15 per cent. salt solution: place a sample of flour for the night in the hot water oven, and treat with ordinary water in the morning: observe in each case that no gluten is produced.

Place aside some moist gluten and water in an outhouse: notice day after day the changes which occur in the appearance and physical properties of the gluten as putrefaction sets in.

Take some carefully washed gluten and grind it up in a mortar with a little 80 per cent. alcohol. Transfer to a flask and keep at a temperature of 40° C. for some hours; filter, and again grind the undissolved residuum with more alcohol in the mortar. Again digest in the flask, and once more repeat this treatment. Evaporate down the mixed filtrates over a water-bath, and notice the transparent yellow gliadin thus obtained. Carefully dry the insoluble portion, which consists of more or less pure glutenin.

The extent to which this series of experiments is carried must depend on the time and opportunities of the student, and also the laboratory facilities at his disposal.

CHAPTER VIII.

ENZYMES AND DIASTATIC ACTION.

243. Hydrolysis.—It has already been incidentally mentioned that starch may readily be converted into dextrin and maltose; with regard to the carbohydrates generally, one of their special characteristics is, that the less hydrated members of the series are easily changed to those containing a higher proportion of hydrogen and oxygen. In consequence of the great importance of these transformations, they will require to be dealt with fully. The present chapter will, therefore, give particulars of the nature of these changes, the agents by which they are effected, and the conditions which are favourable or unfavourable to their occurrence. As the mutations of the carbohydrates consist of the addition of the elements of water to the atoms previously present in the molecule, it has been proposed to include these changes under the general term "hydrolysis." **Hydrolysis is, therefore, defined as a chemical change, consisting of the assimilation, by the molecule of the substance acted on, of hydrogen and oxygen in the same proportions as they exist in water; and resulting in the production of a new chemical compound or compounds.** Those bodies capable of producing hydrolysis are termed "hydrolysing agents" or "hydrolytics." In order that hydrolysis may occur it is obviously necessary that water shall be present.

244. Hydrolytic Agents.—These bodies include oxalic and dilute hydrochloric and sulphuric acids. Commencing with soluble starch, the acids mentioned possess the power of converting that body first into dextrin and maltose, then into glucose. The acid hydrolytics also transform cane sugar into glucose. It will be noticed that the ultimate products of hydrolysis of starch are sugars of various descriptions, hence this operation is frequently termed the "saccharification" of starch.

245. Saccharification of Starch by Acids.—This operation is carried on as a commercial process for the manufacture of glucose for use in brewing. The starch is boiled, either in open vessels or under pressure, with dilute sulphuric acid. If the operation be stopped as soon as a portion of the solution gives no blue colouration when tested with iodine, it will be found that dextrin and maltose are the chief products. Continued boiling results in the transformation of most of the dextrin and maltose into glucose. The sulphuric or oxalic acid, whichever is used, is next removed by the addition of calcium carbonate in slight excess. This reagent forms an insoluble oxalate with the latter acid, and with the former, calcium sulphate, which is only very slightly soluble. The precipitate is allowed to subside and the supernatant liquid evaporated under diminished pressure.

246. Catalysis.—When soluble starch is saccharified by the action of an acid such as oxalic acid, it is found that the acid itself does not disappear during the reaction. If the necessary precautions be taken, the same quantity of unaltered acid is found at the termination of the chemical change as was introduced prior to its commencement. This leads us to institute a comparison between actions of the type now under consideration and others frequently met with in more general chemistry. Taking chemical changes as a whole, they may be resolved into those of two classes, (1) those in which the reaction is practically immediate on the mixture of the interacting bodies, as when hydrochloric acid and sodium hydroxide are added to each other in solution and at once form the neutral sodium chloride, and (2) those in which the chemical change occupies an appreciable time. As an illustration of the latter the combination of sulphur dioxide with oxygen to form sulphur trioxide in the presence of water may be mentioned. Now in the case of many reactions of the second type, there are substances which remarkably accelerate the speed of the reaction, without themselves undergoing a permanent chemical change. Thus, if a small quantity of nitrogen oxide, NO, be added to the aforesaid mixture of sulphur dioxide and oxygen, it marvellously increases the rapidity of combination of these bodies, and that without in itself undergoing permanent alteration. This is, in fact, the method employed in the manufacture of sulphuric acid, and were there no purely secondary reactions, the nitrogen oxide might be entirely recovered as such at the close of the chemical process. **This process of changing the rate of a slow chemical action is termed "catalysis," and the active agent therein is termed a "catalyst."** Among the essentials of catalytic action is that the catalyst does not induce the chemical change but only alters the rate of one already proceeding; and further, the catalyst does not combine with any of the products of the reaction.

In the case of many chemical reactions, an important point is that they only proceed until a certain condition of equilibrium is reached. Thus if a compound is subjected to such conditions as lead to its dissociation into the constituent elements, there is a position in which there will be neither complete combination nor complete dissociation. There will be simultaneously present free atoms or molecules of the elements and molecules of the compound. If an additional quantity of the compound is added, dissociation will proceed until the point of equilibrium is again reached; or if combining proportions of the elements are added, combination will ensue till again the position of equilibrium is attained. In a chemical reaction that is accelerated by the introduction of a catalyst, and in which there is an intermediate point of equilibrium, the same catalyst that speeds the reaction to this point will have a reverse action if added to the substances beyond the equilibrium point. Thus taking the hydrolysis of cane sugar to glucose, there is in fact a point at which the action ceases, and on that point being reached, there is present some cane sugar and also glucose and fructose. If glucose and fructose only be subjected to the action of the same catalyst, a reverse action proceeds until cane sugar and glucose and fructose are present in equilibrium quantities. Thus the same catalyst which hydrolyses cane sugar into the simpler bodies, may also synthesise cane sugar from these substances.

247. Enzymes or Soluble Ferments.—Another most important group of catalytic agents, which are capable of inducing hydrolysis, consists of certain soluble bodies of organic origin. Among such substances are human saliva, filtered aqueous infusions of yeast, flour, bran, and malt. Chemical research shows that in each case hydrolysis is due to the nitrogenous constituents of these various agents. In several instances the active principle has either been isolated or obtained in a very concentrated form; it is not known, however, with certainty whether these bodies are definite chemical compounds, or whether they are only mixtures of certain nitrogenous bodies in a particularly active state.

Classified Lists of Enzymes.

Name of Group.	Function.	Principal Members.	Bodies from which derived.
1. **Cellulolytic**	Solution of cellulose walls of grain.	Cytase.	Green malt.
2. **Amylolytic**	Conversion of starch-paste into soluble starch (liquefaction). Conversion of soluble starch into maltose and dextrin (saccharification). Saccharification only, not liquefaction.	Diastase. Ptyalin. Amylopsin. Barley diastase. Wheat diastase. Reychler's "Artificial diastase" (?)	Malt. Saliva. Pancreatic juice. Raw grain. Raw grain or flour. Wheat gluten.
3. **Inversive**	Conversion of sucrose into glucose.	Invertase. Invertin.	Yeast. Intestinal juice.
	Conversion of maltose into glucose.	Maltase .	Yeast.
4. **Proteolytic**	Conversion of proteins into peptones.	Pepsin or Peptase. Trypsin. Proteolytic enzyme of Malt and other seeds, Protease.	Gastric juice. Pancreatic juice. Germinating grain.
5. **Zymase**	Conversion of sugar into alcohol and carbon dioxide.	Zymase.	Yeast.
6. **Coagulative** ..	Coagulation of protein matter.	Fibrin-ferment. Myosin-ferment. Weyl and Bischoff's Vegetable myosin (?). Rennet.	Blood. Muscle. Wheat flour (?). Gastric juice.
7. **Emulsive**	Conversion of glucosides into glucose and other compounds.	Emulsin. Myrosin.	Almonds. Mustard.
8. **Steatolytic**	Separation of fats into fatty acids and glycerin.	Steapsin.	Pancreatic juice.

These substances form part of a yet larger group of bodies which formerly were indiscriminately classed together as "ferments," that is, bodies which were capable of inducing fermentation. At present this latter term, as is explained in a subsequent chapter, is confined to those chemical actions which are the work of certain micro-organisms; and the changes, such as hydrolysis, that are due to active principles which are not organised or living, form a separate class. These active principles have been termed soluble-ferments; but, as in order to avoid confusion with micro-organisms and fermentation, it is well to dissever them entirely from the idea of fermentation, the term "enzyme" has been proposed, and is now generally adopted. It has also been proposed to group together all the chemical changes due to enzymes under the generic term of "enzymosis."

A number of chemical reactions are brought about by enzymes, most of which, however, are instances of hydration of the bodies acted on. Enzymosis occurs usually most readily at temperatures about 40° C., and is characterised by the fact that a minute quantity of the enzyme is capable of causing the characteristic chemical change in a comparatively enormous quantity of the substance acted on, without itself apparently undergoing change. In other words, these substances behave as catalysts. **An enzyme may therefore be defined as a substance produced by living organisms, and capable of acting catalytically on contiguous compounds.**

248. Chemical Properties of Enzymes.—These substances can be extracted from the bodies containing them by the action of water, dilute alcohol, salt solutions, or glycerin. From these solutions they may be precipitated by strong alcohol, lead acetate, or saturation with ammonium sulphate. This precipitate, on being washed with absolute alcohol and dried in vacuo, yields a friable mass easily reduced to a white powder, and in composition either protein or closely allied to protein matter. The enzymes act most vigorously at a temperature of from 40 to 45° C., and are, in the moist state, destroyed by a temperature of from 50 to 75° C., according to the nature of the enzyme. (Certain enzymes when absolutely dry withstand a temperature of as much as 170° C.) The presence of free acid or alkali, and also small quantities of certain neutral salts, as ammonium sulphate, are inimical to enzymosis.

249. Classification of Enzymes.—Among the number of enzymic actions, comparatively few are of importance in the study of the present subject; these are placed first in the accompanying table, while others of less immediate value, but still of interest as illustrative of the whole scheme of enzymosis, follow.

Osborne and Voorhees' researches rather negative the existence of Weyl and Bischoff's hypothetical vegetable myosin; but, if the contrary were the case, the natural place of this enzyme would be as shown in class 6. The fact that there are members of this class which can perform analogous functions in blood and muscle did much toward paving the way for the inception of the theory of there being a gluten-forming enzyme.

250. Cytase.—As early as 1879, Brown and Heron mentioned that during the germination of grain the cellulose cell-walls, and also the cellulose of the starch granules, are broken down. Brown and Morris again call attention to the same fact in their paper on the "Germination of some of the Gramineæ," *Jour. Chem. Soc.,* 1890, p. 458. As germination proceeds, the parenchymatous cell-walls of the endosperm are gradually dissolved, and ultimately leave no sign of separation between the contents of the contiguous cells. During the progress of these changes the endosperm is much softened, and attains the condition of "mealiness" aimed at by the maltster in course of the germination of barley in malt manufacture. Brown and Morris find that this production of mealiness is undoubtedly co-terminous with the dissolution of the cell-wall, and, contrary to what is usually believed, is entirely independent of the disintegration of the starch-granule. **The enzyme, which thus dissolves the parenchymatous cell-walls of the endosperm, has received the name Cytase.** Cytase is secreted by the embryo during germination, and is found in considerable quantity in green- or air-dried malt, but is readily destroyed by the action of heat, and so is found in only very limited quantity in kiln-dried malt, especially that which has been subjected to a somewhat high temperature. That cytase is not identical with diastase is demonstrated by the fact that, whereas a filtered aqueous extract of air-dried malt dissolves the cell-walls of the endosperm, this power is lost on subjecting the liquid to a temperature of 60° C., which temperature does not destroy the vitality of diastase.

251. Diastase.—Since the "mashing" or maceration of malt with water at about a temperature of 60° C. has been employed as one of the operations in the brewing of beer, it has been well known that during this process the starch of the malt is converted into some form of sugar. Payen and Persoz, in 1833, stated that the action of an infusion of malt on starch was due to the presence of a particular transforming agent to which they gave the name of diastase.

Investigation shows that diastase is secreted by the embryo of such plants as wheat and barley during germination—in a subsequent chapter the physiology of its production and action is dealt with somewhat fully. Diastase is present in large quantity in air-dried malt, and to a lesser but still considerable extent in the malt after kiln-drying.

For its extraction in a concentrated form, Lintner recommends the following method:—1 part of green malt or sifted air-dried malt is extracted with 2 to 4 parts of 20 per cent. alcohol for 24 hours. At the end of this time as much as possible of the liquid is filtered off by means of a press, then filtered through paper until bright. To this filtered extract 2½ times its volume of absolute alcohol is added, resulting in the production of a precipitate, which is allowed to settle, and washed on a filter with absolute alcohol. The precipitate is then transferred to a mortar and rubbed down with absolute alcohol, once more transferred to a filter and washed with absolute alcohol, and ether. Finally it is dried in vacuo over sulphuric acid. Prepared in this manner, diastase consists of a yellowish-white powder of great diastatic activity. Its purification is effected by repeatedly dissolving in water and re-precipitating by alcohol. Subjecting the aqueous solution to dialysis reduces the quantity of ash (which consists of normal calcium phosphate) and also increases the percentage of nitrogen. A purified diastase gave the following numbers on analysis calculated on the ash-free substance. Results of analyses of other enzymes are also given.

Composition of Various Enzymes.

	Diastase.	Pancreatic Enzyme.	Invertase.	Emulsin.
Carbon	46.66	46.57	43.90	43.50
Hydrogen	7.35	7.17	8.40	7.00
Nitrogen	10.42	14.95	9.50	11.60
Sulphur	1.12	0.95	0.60	1.30
Oxygen	34.45	30.36	37.60	36.60
	100.00	100.00	100.00	100.00
Authority	Lintner.	Hüfner.	Barth.	Bull.

More recently Osborne has prepared diastase from malt in another manner. The ground malt was first extracted with water and filtered. To the filtrate ammonium sulphate was added to saturation, and the proteins thus precipitated. The precipitate was suspended in water and subjected to dialysis, thus removing much of the ammonium sulphate; there remained a residue of a globulin character, and this was filtered off. The filtrate was again saturated with ammonium sulphate, the precipitate suspended in water, once more dialysed, and filtered, thus getting rid of most of the globulins. The resulting solution of proteins was next dialysed into alcohol, with the formation of some precipitate. This was filtered off, and the solution again dialysed into more alcohol, with the formation of a further precipitate. The operations of dialysis and filtration were repeated until altogether five fractions of precipitate had been obtained. The precipitates were purified by solution in water, filtration, dialysis first into water, and afterwards into alcohol, and finally re-precipitated by the addition of absolute alcohol and dried. The fourth fraction was far higher in diastatic power than any of the others. This preparation was soluble in water, became turbid at 50° C., and gave a large coagulum at 56° C. The filtrate from this gave the biuret reaction, thus showing the presence of proteoses. This preparation had a diastatic power of 600° Lintner and was the most active diastatic substance on record. Analysis showed it to contain 0.66 per cent. of ash, and allowing for this it had the following composition:—

Carbon	52.50
Hydrogen	6.72
Nitrogen	16.10
Sulphur	1.90
Oxygen	22.78
	100.00

The composition is that of a normal protein, save that the sulphur is somewhat high, but this may be accounted for by the possible presence of a little ammonium sulphate.

On further investigation, this substance was found to have the same coagulating temperature as leucosin (albumin of wheat or barley), and Osborne regards albumin as being the diastatic body. But the amount of diastatic action is not proportional to that of albumin, and therefore Osborne suggests the hypothesis that diastase is a compound of albumin with possibly proteose, but of this theory there is at present no direct proof.

Some time ago, the Malt-Diastase Company of New York forwarded to the authors a sample of exceedingly concentrated malt diastase, prepared in their laboratory, which had the following remarkable converting power:—

(1) One part by weight would convert 150 parts by weight of starch into dextrin and maltose, within ten minutes at 99° F.

(2) One part would produce from a surplus of starch, 329 parts of maltose within thirty minutes at 99° F.

(3) Tested according to Lintner's method, this diastase had a strength of 4,705°.

Diastase gives with tincture of guaiacum and hydrogen peroxide a blue colouration, which is soluble in ether, benzene, chloroform, and carbon disulphide, but not in alcohol. This reaction of diastase is shared by other enzymes, and is caused by the presence of peroxydase. This latter substance may be regarded as an enzyme having an oxidising action as distinct from the hydrolysing actions before described.

Diastase in the pure form does not reduce Fehling's solution, and, as may be judged from its very nature, is marked by a great capacity for liquefying starch paste and saccharifying it into dextrin and maltose. Unlike the acids, diastase, however, is incapable of converting starch further than into dextrin and maltose. Diastase readily changes amylodextrin and maltodextrin completely into maltose, but does not under any circumstances further hydrolyse maltose.

Under favourable circumstances, one part of well-prepared diastase, such as that of Osborne, is stated to suffice for the conversion of 2000 parts of starch. A dilute solution of diastase is exceedingly unstable, rapidly becoming acid, and losing its power of starch conversion. This does not apply to concentrated solutions of diastase in the presence of sugars such as are obtained by concentrating in vacuo cold-water extracts of malt to the consistency of a sirup.

252. Diastatic Action or Diastasis.—The action of diastase, being of such great importance in brewing operations, has been studied closely. The term "diastase" is occasionally used in a generic sense, and is then applied to the hydrolysing agents of the cereals generally; thus cerealin is at times referred to as the "diastase" of bran. **Hydrolysis, when effected by diastase or its congeners, is often termed diastatic action, for which the shorter term "diastasis" is sometimes used.**

253. Measurement of Diastatic Capacity.—The activity of malt extract, or of the purer forms of diastase, depends on the degree of concentration, temperature, and other conditions. Kjeldahl has enunciated what is known as the law of proportionality. The amount of diastase in two malt extracts is proportional to the reducing power which they effect, provided that both act on the same quantity of starch during the same period of time, and that the cupric oxide reducing power (K) does not surpass 25–30. If the whole of the starch present were converted into maltose, K would be 62.5; according to this stipulation, therefore, somewhat less than half the starch must undergo conversion into maltose, or, in other words, starch must be to that extent in excess of the amount hydrolysed by the diastase. Unless the starch is thus largely in excess, the diastatic action will not be proportional to the amount of diastase.

Lintner measures the diastatic capacity on soluble starch, prepared as directed in Chapter VI., paragraph 173, and terms the diastatic activity of the precipitated diastases as 100, when 3 c.c. of a solution of 0.1 gram of diastase in 250 c.c. of water, added to 10 c.c. of a 2 per cent. starch solution, produces in one hour, at the ordinary temperature, sufficient sugar to reduce 5 c.c. of Fehling's solution. These quantities amount to 0.0012 gram of diastase, acting on 0.2 gram of soluble starch, while the maltose necessary to reduce 5 c.c. of Fehling's solution is 0.0400 gram. This quantity of maltose produced is approximately equal to 0.05 gram of starch reduced, and the diastase will have hydrolysed about 41 times its weight of starch in the time and under the conditions specified. Directions for the determination of diastase by methods based on this principle are given in the analytic section of this work. The above is simply a mode of determining diastatic activity, everything else being equal. The consideration of how diastatic capacity is affected by changes of temperature and other conditions is described in detail in subsequent paragraphs.

254. Nature of Diastase.—The effects of diastase on starch have already been spoken of as including two distinct actions; first, the liquefying of starch paste, converting it, in fact, into soluble starch; and second, the saccharifying of this previously liquefied starch. Certain forms of diastase possess this latter power only; but it is usually assumed that malt diastase possesses the two properties. More recently, the opinion has been growing that malt diastase consists of two distinct enzymes—the one a liquefying, and the other a saccharifying agent. More will be said on this matter when dealing with the diastase of unmalted grain.

There naturally arises, in conjunction with the study of diastase, the speculation whether diastase is a distinct chemical compound of nature allied to the proteins, or a property or function certain protein bodies are capable of exercising under special conditions. Certainly, in the purest form hitherto isolated, diastase is obtained by processes which secure soluble proteins in the purest state; and, practically, any substance called diastase is unobtainable as distinct and separate from soluble proteins.

Brown and Heron finding that, on heating malt extract to a temperature of about 46° C., the soluble proteins commence to coagulate; a continuance of this temperature for some 15 to 20 minutes effects the maximum amount of coagulation possible at 46° C. On raising the temperature a few degrees, an additional quantity of proteins coagulate; this further increase of coagulation continues, as the temperature rises, up to about 95° C. The proteins of malt extract may be viewed as being composed of distinct fractions, each of which has a definite coagulating point, varying from 46° to 95° C. With the coagulation of the proteins, the diastatic power of the malt extract diminishes; also, no diminution of starch converting power has been observed without a coagulation of proteins. Further, at the point at which the diastatic power of malt extract is destroyed (80–81° C.), nearly the whole of the coagulable proteins have been precipitated. Brown and Heron "are consequently led to conclude that **the diastatic power is a function of the coagulable proteins themselves, and is not due, as has been generally supposed, to the presence of a distinctive transforming agent.**" They further find that filtration through a porcelain diaphragm results in the production of a liquid which, on being heated to the boiling point, throws down no proteins. This filtered malt extract they find to be incompetent to produce diastasis, possessing "absolutely no transforming power." It is therefore possible to remove the diastatic agent from the malt extract without the application of heat.

255. Action of Diastase on Starch.—This reaction may first be summed up briefly by stating that if a cold infusion of malt be made, and then filtered; it, the infusion, on being added to a solution of starch in water, at temperatures from 15° to about 70° C., more or less rapidly hydrolyses the starch into a mixture of dextrin and maltose. The longer the operation is continued, the higher is the proportion of maltose produced; but even prolonged action does not result in any further hydrolysis of the maltose into glucose. The investigation of starch and its transformation products has for many years occupied the close attention of what may be called the Burton School of Chemists. Prominent among these are the names of O'Sullivan, Brown, Heron, and Morris. By these and other writers, a number of papers of singular interest and value have been contributed to the Journal of the Chemical Society. The following paragraphs (256-262) consist largely of a summary of the conclusions arrived at and adduced in these papers, after careful collation with each other, and the work of other investigators.

BROWN, HERON, AND MORRIS' RESEARCHES.

256. Malt Extract employed.—It was found that a cold aqueous infusion of malt was the most convenient diastatic agent to employ, as diastase when employed in a pure state was liable to considerable variations in activity. With proper precautions, the aqueous infusion of malt admitted of any degree of accuracy. The infusion or malt extract was prepared by mixing 100 grams of finely ground pale malt with 250 c.c. of distilled water. This mixture was well stirred and then allowed to stand for from six to twelve hours, and then filtered bright. This extract had a specific gravity of 1036–1040.

257. Action of Malt Extract on Cane Sugar.—Malt extract is capable of "inverting" cane sugar, i.e., changing it into glucose. The term "inverting" is derived from the fact that the resulting mixture of glucoses exerts a left handed rotary action on polarised light, while the original sugar is dextro-rotary. The maximum effect is produced at about 55° C.; it is much weaker at 60°, almost destroyed at 66°, and entirely destroyed by boiling.

258. Action of Malt Extract on Ungelatinised Starch.—According to Brown and Heron's earlier researches, malt extract is incapable of acting on unaltered starch; and even when contact between the two is maintained for a considerable time, not the slightest action is perceptible at ordinary temperatures.

Notwithstanding this, it is well known that the starch of seeds is attacked and dissolved during the natural act of germination; but this action they viewed as being inseparable from the living functions of the vegetable cell.

This statement is at variance with that of Baranetzky, who avers that "the starch granules of different kinds are acted on with unequal rapidity by the diastatic ferments of plant juices, the strongest ferment of all, malt diastase, being well known to have no perceptible influence, even after long exposure, on solid potato-starch granules, while wheat and buckwheat are dissolved with facility."

In a more recent paper on "Germination of some of the Gramineæ," 1890, Brown and Morris refer to Brown and Heron's paper of 1879, and the conclusion therein expressed is that ungelatinised starch is not acted on by malt extract, no "pitting" of the granule or disintegration being produced by artificial means. They also refer to Baranetzky's memoir, and confirm his statement that solid potato-starch granules (which had been exclusively used by O'Sullivan and themselves in their previous researches) are highly resistant to diastase. They further find that well-washed and highly purified barley-starch is in a few days "pitted," disintegrated, and dissolved by a cold-water extract of air-dried malt, the action being facilitated, as shown by Baranetzky, by the presence of a minute quantity of acid. They treated some well-purified ungelatinised *barley*-starch with a solution of precipitated malt diastase, to which 0.0065 per cent. of formic acid had been added. (Acid of this degree of concentration has no action on barley-starch.) A trace of chloroform had also been employed in order to prevent putrefactive changes. The starch was vigorously attacked, with the production of maltose as the only optically active substance produced.

At higher temperatures, diastase or malt extract acts on ungelatinised starch; thus Lovibond ("Brewing with Raw Grain") states that the diffusive action of the diastase through the starch cell-wall is sufficient at high temperatures, to effect the hydrolysis of the starch granulose. The temperatures at which he worked were, however, not much below those given for incipient gelatinisation. The authors also find that on mashing wheat flour with malt extract for some time at temperatures below the gelatinising point, considerable quantities of starch suffer hydrolysis.

Lintner gives the following table of the quantities of ungelatinised starch dissolved by treatment with malt extract at various temperatures. The digestion was allowed to proceed for four hours, but in the case of the higher temperatures was practically complete in about twenty minutes. The results are given in percentages of the total starch taken for the experiments:—

ACTION OF MALT EXTRACT ON UNGELATINISED STARCH.

	50° C. Per Cent.	55° C. Per Cent.	60° C. Per Cent.	65° C. Per Cent.
Potato Starch	0.13	5.03	52.68	90.34
Rice "	6.58	9.68	19.68	31.14
Wheat "	—	62.23	91.08	94.58
Maize "	2.70	—	18.50	54.60
Rye "	25.20	—	39.70	94.50
Oat "	9.40	48.50	92.50	93.40
Barley "	12.13	53.30	92.81	96.24
Green Malt Starch	29.70	58.56	92.13	96.26
Kilned "	13.07	56.02	91.70	93.62

259. Action of Malt Extract on Bruised Starch.—As the next step in the investigation, some starch was triturated in a mortar with powdered glass. This treatment results in cutting the cellulose envelopes of the granules. The starch granulose is then exposed, and on being treated with malt extract rapidly undergoes conversion. The product consists principally of maltose, the actual results obtained in one experiment being that, after remaining six hours, the clear solution contained—

Maltose	86.3
Dextrin	10.5
Cellulose	3.2
	100.0

After twenty-four hours in the cold the maltose had suffered a slight increase:—

Maltose	91.4
Dextrin	7.0
Cellulose	1.6
	100.0

It will be noticed that under these circumstances a small quantity of cellulose becomes dissolved.

260. Action of Malt Extract upon Starch Paste in the Cold.—At ordinary temperatures malt extract acts upon starch paste (gelatinised starch) with great rapidity and energy. In 100 c.c. of starch solution, containing between 3 and 4 per cent. of solid matter, the addition of from 5 to 10 c.c. of the malt extract causes the starch to become perfectly limpid in from one to three minutes. Immediately after arriving at this point the solution ceases to give a blue colouration with iodine. Amyloïns are shown to be present by the brown reaction with iodine, and do not disappear within some five or six minutes from the commencement of the experiment. In this case also a small quantity of starch cellulose is dissolved, but is slowly re-deposited on the liquid standing. After remaining three hours, three experiments gave a mean of—

Maltose	80.4
Dextrin	19.6
	100.0

as the composition of the solution, resulting from hydrolysis by malt extract.

261. Action of Malt Extract at higher temperatures.—At temperatures of 40° and 50° C., the ultimate products of the action of malt extract are found to be practically the same as in the cold, but the point of disappearance of amyloïns is reached somewhat less rapidly. At 60° C. the action is weakened, but still proceeds sufficiently far to produce practically the same amount of maltose. At still higher temperatures the transformation of the dextrin, first formed, into maltose goes on much more slowly. Also, the action of the diastase of the malt extract may be weakened by the addition to it of dilute alkalies. Such treatment results in limiting the extent to which he conversion of dextrin into maltose proceeds. The results may be summed up by stating that, by modifications of the treatment of starch paste with malt extract, certain fixed points may be obtained representing several different molecular transformations of starch.

262. Molecular Constitution of Starch, Dextrin, and Maltose.—The historical development of the modernly held hypothesis of the molecular constitution of starch is, in view of the importance of the subject, of considerable interest. Brown and Heron, in their paper on "Starch and its Transformations," 1879, considered that the most natural conclusion that can be derived from the varying proportions of dextrin, obtained in modifications of the hydrolysis of starch paste by malt extract, is that there are several dextrins, and that these dextrins are polymeric, and not metameric bodies. Having adopted this view, Brown and Heron's results led them to the opinion that the simplest molecular formula for soluble starch is $10C_{12}H_{20}O_{10}$, which may also be written $C_{12\times10}H_{20\times10}O_{10\times10}$. The first change produced by the addition of malt extract would, then, be represented by—

$$\underset{\text{Soluble Starch.}}{C_{12\times10}H_{20\times10}O_{10\times10}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Erythro-dextrin. }\alpha.}{C_{12\times9}H_{20\times9}O_{10\times9}} + \underset{\text{Maltose.}}{C_{12}H_{22}O_{11}}$$

That is, one of the groups of $C_{12}H_{20}O_{10}$ having combined with water to form maltose, the remaining nine groups constitute the first or most complex dextrin. By the assimilation of another molecule of water, the nine-group dextrin breaks up into a second molecule of maltose and an eight-group dextrin. This reaction proceeds through successive stages until finally the one-group dextrin, $C_{12}H_{20}O_{10}$, is in its turn transformed into maltose. There are thus theoretically possible nine polymeric modifications of dextrin; the two higher of these are erythro-dextrins; the remaining seven are achroo-dextrins. The most stable of the whole of these dextrins is that resulting from the eighth transformation, having the composition $C_{12\times2}H_{20\times2}O_{10\times2}$: the hydrolysis of starch, with the production of this dextrin, would then be represented by—

$$\underset{\text{Soluble Starch}}{C_{12\times10}H_{20\times10}O_{10\times10}} + 8H_2O = \underset{\text{Achroo-dextrin}\ \zeta.}{C_{12\times12}H_{20\times2}O_{10\times2}} + \underset{\text{Maltose.}}{8C_{12}H_{22}O_{11}}.$$

In the paper by Brown and Morris ("The Non-crystallisable Products of the Action of Diastase upon Starch," 1885), they adduce evidence in favour of a third body, maltodextrin, being formed as an intermediate product during the hydrolysis of starch; as previously mentioned, they ascribe to this body the formula, $\begin{cases} C_{12}H_{22}O_{11} \\ C_{12}H_{20}O_{10} \\ C_{12}H_{20}O_{10} \end{cases}$. From this it will be seen that maltodextrin is composed of a molecule of maltose united with two of the one-group dextrin. Viewed in the light of the existence of this intermediate product, they then regarded the following as the simplest molecular formula for starch, capable of accounting for the various reactions observed during its hydrolysis—

$$\begin{cases} (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \end{cases}$$

In accordance with this hypothesis, the first step in hydrolysis consists in the lesion of one of the ternary groups, which is transformed into maltodextrin by the assimilation of a molecule of water, thus—

$$\underset{\substack{\text{One of the five ternary groups}\\ \text{constituting the starch molecule.}}}{(C_{12}H_{20}O_{10})_3} + \underset{\text{Water.}}{H_2O} = \underset{\text{Maltodextrin.}}{\begin{cases} C_{12}H_{22}O_{11} \\ (C_{12}H_{20}O_{10})_2 \end{cases}}$$

Malt extract effects the complete conversion of maltodextrin into maltose—

$$\underset{\text{Maltodextrin.}}{\begin{cases} C_{12}H_{22}O_{11} \\ (C_{12}H_{20}O_{10})_2 \end{cases}} + \underset{\text{Water.}}{2H_2O} = \underset{\text{Maltose.}}{3C_{12}H_{22}O_{11}}.$$

In the change producing maltodextrin, the remaining four ternary groups of $(C_{12}H_{20}O_{10})_3$ unite to form the most complex of the dextrins. As the hydrolysis continues, the remaining ternary groups undergo successively the same change until one only remains: this is identical with that before referred to as achroo-dextrinζ. The view that the starch molecule contains fifteen of the $C_{12}H_{20}O_{10}$ group instead of ten, requires that this, which may be distinguished as "stable dextrin," shall consist of three groups of $C_{12}H_{20}O_{10}$ instead of two: this, of course, makes the formula the same as that of one of the ternary groups. The reaction for the production of stable dextrin is then represented by the following equation:—

$$\underset{\text{Soluble Starch.}}{\begin{cases} (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \end{cases}} + \underset{\text{Water.}}{12H_2O} = \underset{\text{Stable Dextrin.}}{\begin{cases} C_{12}H_{20}O_{10} \\ C_{12}H_{20}O_{10} \\ C_{12}H_{20}O_{10} \end{cases}} + \underset{\text{Maltose.}}{12C_{12}H_{22}O_{11}}.$$

Such, very briefly summarised, were the opinions advanced by Brown, Heron, and Morris, up to 1885, as to the relative molecular constitutions of starch, dextrin and maltose.

In 1888 and 1889, Brown and Morris contributed to the *Chemical Society's Journal* two most important papers on "The Molecular Weights of the Carbohydrates." To these papers reference has already been made in the commencement of Chapter VI. By the application of Raoult's method, the molecular weights of starch and the products of its hydrolysis were definitely determined. Among these determinations, probably the most important was that of dextrin. This was made as a preliminary to the estimation of that of soluble starch. It has been already shown that these chemists view starch as a compound of five dextrin groups. In their 1889 paper they say:—

"When the complex molecule of starch is broken down by diastase, under the conditions most favourable to its complete hydrolysis, we have shown that a point of equilibrium, or, speaking more strictly, a resting point in the reaction is reached, when the amount of dextrin produced corresponds to *one-fifth* by weight of the amount of starch taken; that is, when the mixed products have $[\alpha]\ j_{3\cdot86} = 162.6°$ and $K_{3\cdot86} = 49.3$.

"This reaction is represented in the simplest form by

$$\underset{\text{Starch.}}{5C_{12}H_{20}O_{10}} + \underset{\text{Water.}}{4H_2O} = \underset{\text{Dextrin.}}{C_{12}H_{20}O_{10}} + \underset{\text{Maltose.}}{4C_{12}H_{22}O_{11}}$$

"If the production of maltose and dextrin during hydrolysis is to be considered as due to a molecular degradation of the starch, and we think the evidence in favour of this is almost conclusive; then, no matter what view we may take of the actual manner in which this degradation takes place, we cannot escape from the conclusion that *the molecule of stable dextrin of the above equation is one-fifth of the size of the soluble starch molecule from which it has been derived.*"

Brown and Heron determined by Raoult's method the molecular weight of this dextrin, and thus indirectly that of starch. In the next place they proceeded to consider whether Raoult's method was capable of throwing any light on the relations of the dextrins to each other, it being a matter of the highest theoretical importance to determine whether these bodies constitute a series of polymers, or whether they stand merely in metameric relation to each other. Accordingly some of the so-called higher dextrins were prepared; that is, those which result from starch hydrolysis arrested at its earlier stages. A comparison of the results obtained afforded no evidence of there being any difference in the molecular weights of the higher and lower dextrins. Brown and Morris summarise their conclusions by saying that there being no differences in the various dextrins when treated by Raoult's method, "goes, in our opinion, a long way towards proving that, after all the dextrins are metameric, and not polymeric. If this is admitted as even probably correct, it becomes necessary to consider how far our previous views on the breaking-down of the starch molecule must be modified in order to include the new facts." Brown and Morris enunciate the following hypothesis as being more in accord with the facts:—

"We may picture the starch-molecule as consisting of four complex amylin-groups arranged round a fifth similar group, constituting a molecular nucleus.

"The first action of hydrolysis by diastase is to break up this complex molecule, and to liberate all the five amylin-groups. Four of these groups when liberated are capable, by successive hydrolysations through malto-dextrins, of being rapidly and completely converted into maltose, whilst the central amylin nucleus, by a closing up of the molecule, withstands the influence of hydrolysing agents, and constitutes the stable dextrin of the low equation, which, as we know, is so slowly acted upon by subsequent treatment with diastase. The four readily hydrolysable amylin-groups we look upon as of equal value, and in their original state these constitute the so-called high dextrins, which can never be separated completely from the low dextrin by any ordinary means of fractionation.

"This hypothesis provides for intermediate maltodextrins or amylodextrins, whose number is only limited by the size of the original amylin-group.

"Each amylin-group of the five has a formula of $(C_{12}H_{20}O_{10})_{20}$, and a molecular weight of 6480; so that the entire starch-molecule, or, more correctly speaking, that of soluble starch, is represented by $5(C_{12}H_{20}O_{10})_{20}$, having a molecular weight of 32,400."

In their *Text Book of the Science of Brewing*, published in 1891, Moritz and Morris further explain that probably the outer amylin-groups cannot exist as such, but immediately on separation from the central nucleus are partially hydrolysed, yielding amyloïns of possibly the very highest type. These amyloïns are gradually hydrolysed, being split up into smaller aggregations, which constitute the various maltodextrins.

Brown and Millar, in a paper contributed to the *Journal of the Chemical Society* in 1899, point out that the so-called stable dextrin has a cupric reducing power of R 5.7–5.9, and therefore must contain a glucose group. According to this view, the hydrolysis of starch is thus represented:—

$$\underset{\text{Starch.}}{100C_{12}H_{20}O_{10}} + \underset{\text{Water.}}{81H_2O} = \underset{\text{Maltose.}}{80C_{12}H_{22}O_{11}} + \underset{\text{Stable Dextrin.}}{\left\{\begin{matrix}(C_6H_{12}O_5)_{39}\\ C_6H_{12}O_6\end{matrix}\right.}$$

263. Effect of Heat on Diastasis.—The rapidity of diastatic action is considerably influenced by variations of temperature; extreme cold practically inhibits it. Starting from ordinary temperatures, diastasis rapidly increases as the temperature rises, until, according to Kjeldahl, 54° C. (129° F.) is reached—from that temperature until 63° C. (145° F.) it remains fairly constant, and then rapidly decreases with any further rise in temperature, being entirely destroyed at 80–81° C. (176–177.8° F.). Lintner, working with soluble starch, places the optimum temperature at 50–55° C. (122–131° F.).

Lintner carefully investigated the effect of heat on diastase itself by dissolving similar quantities of diastase in water, and then heating the various solutions to 55° C. (131° F.) for varying periods of time, and then determining the quantity of each solution requisite to convert the same amount of starch. He obtained the following results:—

Of the untreated solution 0.55 c.c. was required.
After heating 20 minutes at 55° C., 1.10 c.c. of solution were requisite.
" 40 " " 1.75 c.c. " "
" 60 " " 2.22 c.c. " "

By prolonged subjection to this temperature the diastase was much weakened; but, where starch and its transformation products are present, the diastase does not suffer to a like extent on subjection to this temperature, the strength being reduced by about only half the amount when heated in water alone. These results should be compared with those of Brown and Heron, quoted in paragraph 254, on Nature of Diastase.

264. Effect of Time and Concentration on Diastasis.—Other conditions being the same, the time occupied in producing a given amount of reaction depends on the quantity of diastase present. Concentration within wide limits has little effect on the rapidity of diastatic action: Kjeldahl states that equal quantities of diastase, acting at the same temperature and for the same period of time, effect the same amount of conversion in solutions differing widely in degree of concentration.

265. Other Conditions Favourable and Inimical to Diastasis.—Kjeldahl states that very minute quantities of sulphuric, hydrochloric, and organic acids accelerate diastasis, but large quantities retard it. Lintner states that sulphuric acid, to the extent of 0.002 per cent., very slightly increases the activity of diastase; that 0.01 per cent. retards it, and 0.10 per cent. exercises a destructive action. He also finds that 0.001 per cent. of ammonia retards diastasis, 0.005 per cent. almost, and 0.2 per cent. entirely stops the reaction. The influence, not only of these, but, of course, other substances, depends on their degree of concentration. Speaking generally, acetic and hydrocyanic acids, strychnine, quinine, and the salts of these bases, very slightly retard the action of diastase. Alkaline carbonates, dilute caustic alkalies, ammonia, arsenious acid, and magnesia, exercise a somewhat greater retarding influence, depending on the amount of these bodies added. The following bodies completely prevent the action of diastase upon starch—nitric, sulphuric, phosphoric, hydrochloric, oxalic, tartaric, citric, and salicylic acids; caustic potash, soda, and lime; copper sulphate and acetate; mercury chloride, silver nitrate, iron persulphate, alum, and borax. Among antiseptics, formic aldehyde acts energetically, on many of the enzymes. On the other hand —alcohol, ether, chloroform, thymol, creosote, essence of turpentine, cloves, lemon, mustard, etc., exert no retarding influence.

In cases where it is desired to suddenly arrest the action of diastase in chemical changes, salicylic acid forms a convenient agent. In 100 c.c. of solution, 0.040 gram of salicylic acid almost destroys the activity of the diastase in 5 c.c. of 40 per cent. malt extract solution, while 0.050 gram completely arrests all action. In any material containing diastase and starch, treatment with *boiling* 80 per cent. alcohol completely paralyses any subsequent action of the diastase without gelatinising the starch.

Where it is wished to prevent fermentation or putrefaction without retarding diastasis, the addition of small quantities of chloroform or thymol produces the desired effect. Chloroform is conveniently used in the form of chloroform water, containing 5 c.c. of chloroform to the litre. Toluene may also be employed for the same purpose, and is very slightly if at all harmful to enzymes.

266. Ptyalin and Amylopsin.—Ptyalin is found in human saliva, and at an optimum temperature of 35° C. converts starch paste into dextrin and maltose; the reaction being identical with that produced by diastase. Ptyalin acts best in a neutral medium, but is but little affected by small amounts of alkali; a very small quantity of acid, however, arrests its activity, consequently the diastatic action of ptyalin is destroyed on the mixture of food and saliva encountering the acid gastric juice of the stomach. Ptyalin is without effect on cellulose, and hence intact starch granules are not digested by its action.

Amylopsin is an enzyme, very similar to ptyalin, found in the pancreatic juice, where it performs important digestive functions on starchy foods.

267. Raw Grain Diastases.—Earlier observers have pointed out that barley contains more coagulable proteins than does malt, yet fresh barley extract exerts but little diastatic action. Experiments, on which these observations were based, were made with starch-paste, but more recent investigations in which soluble starch was employed show that in some cases raw barley is more actively diastatic than is the green malt prepared from it. Both from barley and wheat a diastase may be obtained by the same methods as employed for its extraction from malt, that is, by treatment with 20 per cent. alcohol, subsequent precipitation of the filtered alcoholic extract with absolute alcohol, and drying in vacuo over sulphuric acid. Lintner and Eckhardt have examined this enzyme in order to determine whether or not it is identical with malt diastase. For this purpose they took quantities of malt and barley extracts respectively, having the same diastatic value as determined by Lintner's method, and subjected soluble starch to their action at varying temperatures. They found that malt diastase had the greatest activity at 50° C., and the most favourable period at 50-55° Raw grain diastase, on the other hand, showed the greatest activity at 50, and the most favourable period at 45-50°. At 4° the raw grain diastase had as high a reducing power as was possessed by that of malt at 14.5°. The conclusion is that the two forms of diastase are distinct from each other.

A more marked and important distinction between these two enzymes is the inability of that from raw grain to effect liquefaction of starch-paste, while if by some other means such liquefaction is effected, raw grain diastase energetically converts the soluble-starch into dextrin and maltose. Brown and Morris notice that the power to liquefy starch-paste and to erode the starch-granule go hand in hand: the observed presence or absence of either property affords safe ground for predicting the presence or absence of the other of the two. But Baker in a paper communicated to the *Journal of the Chemical Society* in 1902, points out that he was able to completely liquefy starch-paste by barley diastase, in from two to three hours at 50° C., with the production of dextrin and maltose. The raw grain diastase is probably an unused residue of an enzyme produced during the previous history of the plant.

268. Invertase.—Although diastase is unable to carry the hydrolysis of starch further than into maltose, yet, as already stated, there is evidence of malt extract containing an enzyme capable of converting cane-sugar into glucose. Brown and Heron adduce experimental proof of this point in a contribution to the *Journal of the Chemical Society,* Vol. XXXV, 1879, page 609; they show that a cane-sugar solution, after being digested for 16 hours as 55° C. with cold water extract of malt, contained 20.4 per cent. of glucose. If, on the other hand, the malt extract were previously boiled for 15 minutes, the percentage of invert sugar was reduced to 0.2 per cent. This enzyme has been termed zymase, but is now known as invertase, the former name being applied to another enzyme, which will subsequently be described. For practical purposes the principal source of invertase is beer-yeast, from which it may be separated in a fairly concentrated form. O'Sullivan and Tompson recommend for this purpose that sound brewers' yeast be pressed, and then kept at the ordinary temperature for a month or two, during which time it does not undergo putrefaction, but changes into a heavy yellow liquid. On filtering, this yields a clear solution of high hydrolytic power, containing all the invertase of the yeast in solution. This liquid has a specific gravity of about 1080, and is termed "yeast liquor" by O'Sullivan and Tompson. This liquor remains for a long time unaltered, except for a darkening of colour. On adding spirit to yeast liquor till it contains 47 per cent. of alcohol, the invertase is precipitated, and may be washed with spirit of the same strength and dried in vacuo, or preserved as a solution by extracting the precipitate with 20 per cent. alcohol, and filtering, when the filtrate contains the invertase.

Invertase acts rapidly on cane-sugar according to the equation:—

$$\underset{\text{Cane-sugar.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Glucose.}}{C_6H_{12}O_6} + \underset{\text{Fructose.}}{C_6H_{12}O_6}.$$

The speed of inversion increases rapidly with the temperature until 55-60° is reached. At 65° invertase is slowly, and at 75° immediately destroyed. Minute quantities of sulphuric acid are exceedingly favourable to the action, but a slight increase of acidity beyond the favourable point is very detrimental. A sample of invertase which had produced inversion of 100,000 times its own weight of cane-sugar was still active; and further, invertase itself is not injured or destroyed by its action on cane-sugar. There is evidently no limit, therefore, to the amount of sugar which can be hydrolysed by a given amount of invertase. The caustic alkalies, even in very small proportions, are instantly and irretrievably destructive of invertase. Invertase is without action on starch, dextrin, maltose, glucose, fructose and gum.

Osborne has prepared invertase in an exceedingly pure form, and finds it to give none of the protein reactions, except precipitation by copper sulphate, lead acetate, and phospho-tungstic acid; though it gave Millon's, the xanthoprotein, and biuret reactions very faintly. He therefore concludes that it is not protein in nature.

269. Maltase.—In addition to invertase, Lintner regards yeast as containing another and distinct enzyme, to which has been given the name of maltase. This body possesses the power of changing maltose into glucose.

270. Intestinal Invertase.—The secretions of the small intestines contain an enzyme allied to the invertase of beer-yeast, inasmuch as it inverts cane-sugar into glucose and fructose; it also inverts maltose into glucose, thus differing from the invertase of yeast, which has no action on maltose. Brown and Heron state that it acts on starch, but Halliburton is of opinion that the bulk of evidence is against the presence of any such diastatic action.

271. Pepsin, or Peptase, and Trypsin.—Collectively, the fluids of the stomach are known as gastric juice, and contain an active proteolytic enzyme termed pepsin. Pepsin may be obtained from the mucous membrane of the stomach by extraction with glycerin, in which pepsin is soluble. The pepsin is precipitated from its glycerin solution by alcohol, dissolved in water and freed from salts and peptones by dialysis. Pepsin is soluble in water to a mucous liquid, but is insoluble in alcohol or ether. Pepsin has been prepared by Pekelharing in a comparatively pure state; he finds it to give the majority of protein reactions, but not to contain phosphorus, thus negativing any possibility of its belonging to the nucleo-proteins. In the presence of an acid, preferably hydrochloric, pepsin attacks and rapidly dissolves insoluble protein substances, as the white of hard-boiled eggs or lean beef, converting them into peptones. Pepsin is most active at about 40° C., and loses its power on exposure to 57-58°. The acid condition is necessary to its action, and is supplied in the gastric juice by the presence of hydrochloric acid, which in the gastric juice obtained from the human stomach amounts to 0.02 per cent., and in that of the dog to 0.30 per cent. The energy of pepsin is impaired, and at last arrested by the peptones produced. Dried pepsin may now be obtained as an article of commerce, being prepared by drying under 100° F. the fresh mucous lining of the stomach of the pig, sheep, or calf. In accordance with the scheme of nomenclature in which the names of the enzymes end in *ase*, the name of this body is frequently written peptase.

Trypsin occurs in the pancreatic juice, and is allied in its general behaviour to pepsin, possessing like it the power of converting proteins into peptones. It differs, however, in the fact that it acts best in an alkaline medium, and less energetically in neutral or slightly acid solutions. The action is arrested by the presence of hydrochloric acid in excess.

272. Proteolytic Enzyme of Resting and Germinating Seeds.—Seeds generally appear to contain a proteolytic enzyme in the form of a zymogen, which during the act of germination becomes converted into an active enzyme, termed protease. This body converts the proteins of the seed into peptones, leucin, and tyrosin. Malt extract exerts a marked physical and chemical effect on the proteins of flour during bread fermentation, a result due to the presence of a proteolytic enzyme, or form of protease.

273. Zymase.—Researches by Buchner and others, (*Berichte d. Deutsch. chem. Ges.*, 1897) have shown that when yeast is ground up with sand and kieselguhr, and then subjected to filtration under hydraulic pressure, a liquid is obtained which is free from yeast cells, and yet is capable of converting sugar in solution into alcohol and carbon dioxide. The chemical action commences in something under an hour and continues regularly for some days. By treatment with alcohol, an active principle can be separated from the yeast filtrate. Buchner proposed the name zymase for this substance, and has proved its action to be due neither to yeast cells nor to fragments of yeast protoplasm contained in the liquid. Zymase is, therefore, to be regarded as a definite member of the enzyme group.

274. Other Enzymes.—Among other enzymes mentioned in the classified list previously given, a word should be said about those included in the group of coagulative enzymes. The coagulation of blood on leaving the body is due to an enzyme; so also is that of muscle at death, in the case of the stiffening termed *rigor mortis*, known in this instance as the myosin-ferment or enzyme. Interest attaches to this, as the animal analogue of Weyl and Bischoff's hypothetical myosin, to which they ascribe the formation of gluten in the doughing of wheaten flour.

Space does not permit any further reference to the emulsive and steatolytic enzymes.

DETAILS OF APPLIED HYDROLYSIS.

275. Empirical Statement of Hydrolysis of Starch.—It will be seen that the formulæ, representing the probable constitution of the molecules, are much more complex that the empirical formulæ respectively of starch and dextrin. The following empirical equation represents in the simplest possible manner the above reaction; it must not, however, be viewed as representing the true nature of the molecular change involved:—

$$\underset{\text{Soluble Starch.}}{(C_6H_{10}O_5)_5} + \underset{\text{Water.}}{2H_2O} = \underset{\text{Dextrin.}}{C_6H_{10}O_5} + \underset{\text{Maltose.}}{2C_{12}H_{22}O_{11}}.$$

276. Hydrolysis of Cane-Sugar.—This operation is slowly effected by the action of malt extract, or even by prolonged boiling with water, which effects the same change more or less completely. At ordinary temperatures, dilute sulphuric and hydrochloric acids are capable of slowly inverting cane-sugar; at temperatures of from 65° to 70° C. the hydrolysis occurs with extreme rapidity. For laboratory purposes, complete inversion is effected by adding to the moderately strong sugar solution one-tenth its volume of strong hydrochloric acid, and then heating the mixture in a water-bath until the temperature reaches about 68° C. The change consists of the cane-sugar molecule splitting up into two molecules of glucose, the one being dextro and the other lævo-rotary—

$$\underset{\text{Cane-Sugar.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Dextro-glucose.}}{C_6H_{12}O_6} + \underset{\text{Lævo-glucose.}}{C_6H_{12}O_6}$$

Invertase also effects this change, and possibly may be employed commercially for the purpose. O'Sullivan recommends its employment in the laboratory for the hydrolysis of cane-sugar as a step towards its analytic estimation.

277. Hydrolysis of Dextrin.—By the action of acids, and also of malt extract, this body may be entirely converted into maltose: the nature of the chemical change has been described when treating of the hydrolysis of starch. Under ordinary conditions, neither invertase nor yeast itself is capable of effecting the hydrolysis of dextrin.

278. Hydrolysis of Maltodextrin.—This change is readily effected by the action of malt extract, but not by either invertase or yeast.

279. Hydrolysis of Maltose.—Maltose is a more stable sugar than is cane-sugar: dilute acids effect its conversion with slowness; thus a maltose solution may be boiled for some minutes with dilute sulphuric acid without undergoing change. Complete inversion results from keeping the solution at a temperature of 100° C. for some six or eight hours. The principal product of inversion is glucose. As has been previously stated, malt extract has no hydrolysing action on maltose. Invertase also is without action on maltose, but maltase effects its hydrolysis.

280. Composition of Malt.—Prior to dealing with the saccharification of malt, some information should be given of its composition. Treatment of the general questions of the transformation of barley into malt must be postponed until the subject of the physiology of grain life is being discussed. Malts differ from barley in that the protein constituents show proofs of considerable degradation. Hilger and Van der Becke have examined barley, barley softened by steeping in water, fresh or green malt (unkilned), and kiln-dried malt. The following table gives the percentage of nitrogen, and of the various nitrogenous constituents:—

NITROGENOUS CONSTITUENTS OF BARLEY AND MALT.

	Barley.	Softened Barley.	Fresh Malt.	Dried Malt.
Total Nitrogen	1.801	1.750	1.751	1.542
Nitrogen of Insoluble constituents	1.6789	1.6853	1.372	1.165
„ as Albumin (soluble) ..	0.0600	0.0354	0.1571	0.1194
„ as Peptone .. :	0.0046	0.0009	0.0058	0.0233
„ as Ammonium Salts ..	0.0169	—	0.0290	0.0057
„ as Amino-acids ..	0.0417	0.0294	0.1417	0.2257
„ as Amides	—	—	0.0505	0.0029

It will be seen that the insoluble proteins have diminished in quantity, while the albumin has increased; so also have the products of further degradation, peptone, amino-acids, and amides.

The starch in barley also suffers considerable diminution; Brown and Morris found the quantities of starch in barley before and after germination to amount to

STARCH IN 1000 CORNS.

	Starch in Barley before Germination.	Starch in Barley after Six Days' Germination.	Loss of Starch.
Expt. 1	20.0552 grams.	15.4398 grams.	4.6154 grams.
„ 2	19.9158 „	15.3636 „	4.5522 „

Taking the mean of the two experiments, 22.5 per cent. of the starch has disappeared. A portion of this has been dissipated as carbon dioxide gas, a portion will have constituted the material from which the new parts of the plant have been formed, while a third portion will have been changed into sugars, which remain in the malt at the end of its manufacture. The increase of sugars is well shown in the following table, which gives in percentages the results of analyses of barley before and after germination, by O'Sullivan.

SUGARS IN BARLEY BEFORE AND AFTER GERMINATION.

	No. 1 Barley		No. 2 Barley	
	Before Germination.	After Germination.	Before Germination.	After Germination.
Sucrose (Cane-Sugar) ..	0.9	4.5	1.39	4.5
Maltose	1.1	1.2	0.62	1.98
Dextrose		3.1		1.57
Lævulose		0.2		0.71

It will be seen that cane-sugar forms a very notable constituent of malt, and also that the other sugars are present in large quantity.

The percentage of acid considerably increases in grain during malting; assuming acidity to be due to lactic acid, Belohoubek gives the following:—

Barley	0.338 per cent. as lactic acid.
Green Malt	0.590 ,, ,, ,,
Kilned Malt	0.942 ,, ,, ,,

In English malts, however, the percentage of acid is considerably less than this, being usually about 0.2 per cent.; so much as 0.4 per cent. is viewed as an indication of unsoundness. Although the acidity of malt is usually returned as lactic acid, a considerable amount is due to the presence of acid phosphates; but, obviously, acidity due to this cause cannot increase during malting.

The following table gives the approximate composition of malt, based principally on analyses by O'Sullivan:—

APPROXIMATE COMPOSITION OF MALT.

	Per Cent.		Per Cent.
Starch	44.00	to	50.00
Sugars	9.00	,,	16.00
,, These include Sucrose, from ..	4.50	,,	16.00
,, Maltose, ,, ..	1.20		
,, Dextrose, ,, ..	1.65		
,, Lævulose, ,, ..	0.20		
Unfermentable Carbohydrates, not Dextrin	5.00	,,	7.00
Cellular Matter (Cellulose)	10.00	,,	12.00
Proteins, soluble in cold water	3.0	,,	4.50
,, insoluble ,, ...	8.00	,,	10.00
Fat	1.50	,,	2.00
Ash	1.90	,,	2.60
Water	2.50	,,	7.00
Acid reckoned as Lactic Acid	0.20	,,	0.40

281. Saccharification of Malt during the Mashing Process.—This process is of interest both from the technical point of view, as being largely used by the baker, and also scientifically, as representing an important example of hydrolysis by malt extract. Malt contains the active hydrolysing principle, diastase, and also from 44 to 50 per cent. of starch. In the operation of malting, the walls of the starch granules get more or less ruptured and fissured; hence the interior granulose is at the outset somewhat exposed to the action of the diastase. As a first step toward the preparation of beer, the brewer treats his ground malt with water at a temperature of from 65.5° C. (150° F.) to 71.1° C. (160° F.). This results in the conversion of the starch present into dextrin and maltose. This operation he terms "mashing." The first change is that the starch becomes gelatinised, and is then freely susceptible to the action of diastase. At temperatures below the gelatinising point of starch, diastasis also proceeds, but somewhat more slowly (comp. Lintner's table, par. 258). At a temperature of about 60° C. (140° F.) almost all the starch, and also the amyloïns, will have disappeared in about twenty minutes; this point may be ascertained by taking out a drop of the liquid and testing it with iodine. An increase of temperature weakens the action of the diastase; hence a mashing made at 60° C. (140° F.) yields in two hours, for the same malt, about 7 per cent. more dextrin and maltose than when mashed at 76.6° C. (170° F.). Further, as might be expected from the results already mentioned, the proportion of dextrin is much greater in the mashing made at 76.6° C. than at 60° C. The duration of the mashing operation has also an influence on the amount of dextrin and maltose produced. With a temperature of 62.7° C. (145° F.) most of the starch is converted into dextrin and maltose within thirty minutes, but for some time after, the yield of these continues to slightly increase. The proportion of maltose to dextrin also becomes higher with a longer mashing. The following is the result of an experiment by Graham:—

Length of Mashing.	Percentage of Maltose.	Percentage of Dextrin.	Total percentage of Maltose & Dextrin.	Ratio of Maltose to Dextrin.
½ hour	48.60	14.61	63.21	3.3 : 1
1 "	52.35	12.26	64.61	4.2 : 1
2 hours	53.56	11.39	64.95	4.7 : 1
3 "	54.60	11.05	64.65	4.9 : 1
7 "	61.47	3.53	65.00	17.4 : 1

It will be seen that by far the greatest proportion of the transformation is effected within the half-hour, while for all practical purposes the hydrolysis is completed within two hours at the furthest.

282. Mashing Malt together with Unmalted Grain.—The diastase of good malt is not merely capable of saccharifying its own starch, but is competent also to hydrolyse in addition considerable quantities of starch from other sources; hence, in brewing operations, malt is frequently mixed with flour from other cereals, either rice or maize being commonly chosen. The diastase of the malt saccharifies the whole of the starch present; but with the proportion of malt unduly low, the ratio of maltose to dextrin produced is comparatively small.

Experimental Work.

283 Hydrolysis of Starch.—Mix 10 grams of starch with 200 c.c. of water, and gelatinise by placing in the hot water-bath. Take 50 c.c. of this solution and add to them 10 c.c. of five per cent. sulphuric acid. Maintain at a temperature of 100° C. until a few drops, taken out with a glass rod or tube, and placed on a porcelain tile, give no blue colouration on addition of iodine. To the solution add precipitated calcium carbonate, or powdered marble, until it ceases to produce effervescence.

Allow the precipitate to subside, and filter; taste the clear solution, notice its sweetness. Test a portion of this filtered solution with Fehling's solution, a red precipitate is produced, showing that either maltose or glucose is present.

To a test tube, containing another portion of the original starch solution, add some saliva, and stand it in a water-bath at a temperature of about 40° C. for some time; notice that the solution becomes more limpid, and ultimately that it gives no starch reaction, on a few drops being taken out and treated with iodine. Test now for maltose, by means of Fehling's solution; a red precipitate is produced. As a complement to this experiment, boil some corn-flour and water, allow the paste to cool, place a spoonful in the mouth, retaining it there for some fifty or sixty seconds, and mixing it with saliva by means of the tongue: notice that the paste becomes limpid, and acquires a sweet taste.

Take some fresh compressed yeast, mix a little with some of the starch solution and place in the water-bath at 40° C. Notice that after several hours the starch remains unaltered, giving a blue colouration with iodine, and little or no reaction with Fehling's solution. Prepare some "yeast-water" by shaking up about 50 grams of the compressed yeast with 150 c.c. of cold water; let this stand for from four to six hours, shaking occasionally, then allow to subside and filter the supernatant liquid. Treat some starch solution with this yeast-water in the same way as with the yeast itself: notice that this also causes no alteration in the starch.

Make an aqueous extract of malt, as described in paragraph 256. Take some sound wheat starch, examine it under the microscope, to see that none of the granules are fissured or cracked. Add some of the malt extract to a portion of this starch, and allow it to remain for some hours at a temperature of 20° C. Maintain another similarly prepared sample at a temperature of 40° C. for from six to twelve hours. At intervals from the time of starting the experiment, and at the end of the time, examine the starch in each case carefully under the microscope, in order to see whether any of the granules show signs of cracking or pitting. Make a comparative series of experiments on potato starch. In every experiment, at the end test the starch granules with iodine, in order to see whether they still give the starch reaction.

Shake up some starch with water, and filter: notice that the clear filtrate gives no reaction with iodine. Rub a little of the starch in a mortar with powdered glass; this cuts the cellulose envelopes. Shake up with water, and filter; to the clear filtrate add iodine solution: a blue colouration shows the presence of soluble starch. To some of the bruised starch add malt extract, and allow to stand for twenty-four hours at 20° or 25° C., examine under the microscope, and notice that much of the interior of the cells is dissolved away. Treat a little with iodine, and examine under the microscope in order to determine how much unaltered starch remains. Make some starch paste, as described in paragraph 260; treat it with malt extract as there mentioned, and at intervals of a minute take out a drop of the solution by means of a glass rod, and test with iodine on a porcelain tile. Note the time when the starch and the amyloïns disappear. Make a series of similar experiments with varying temperatures, rising by 10° C. at a time, from 15° C. to the point at which diastasis ceases. The quantities of solution should be measured; and in each case, both the starch and the malt extract solutions should be allowed to stand in the water-bath, regulated to the desired temperature, until both have acquired that temperature, *then* mix the two and note the time.

If desired, the bath may be regulated for this experiment by means of the regulator described and figured in Chapter XI.; in that case it is not absolutely necessary to get the temperature nearer than a degree, but the exact temperature, as read by a thermometer, should be noted.

Make a cold aqueous infusion of bran or pollard in the same way as described for malt, and treat starch solution with it, as was done with the malt extract, both in the cold and at higher temperatures. If separated wheat germ is obtainable, make a similar series of experiments with that substance.

284. **Hydrolysis of Cane-sugar.**—Mix cane-sugar solution with strong hydrochloric acid, and heat to 68° or 70° C., as described in paragraph 276. After hydrolysis, test for reducing sugars by Fehling's solution. To another portion of the cane-sugar solution add some yeast-water, and maintain for three or four hours at 40° C., after which test for maltose or glucose by means of Fehling's solution.

285. **Mashing of Malt.**—Take 100 grams of ground malt, and mix with 500 c.c. of water at 60° C. in a large beaker; weigh the beaker and its contents, and place it in a water-bath at 60° C. Stir occasionally, and from time to time take out small quantities of the well-stirred liquid on the end of a glass rod, and test for starch by iodine solution. Note how long it is before the starch disappears; as soon as iodine produces no blue reaction, wipe the outside of the beaker, place it in the balance, and add distilled water until that lost by evaporation has been replaced: when this point is reached the beaker weighs just the same as before being placed in the bath. Then filter the clear solution, cool rapidly to 15° C., and take the density by means of a hydrometer. The method of using the hydrometer, and the conclusions to be drawn from the density of the wort, are described in the paragraph on "Specific Gravity of Worts" in Chapter XII. Make similar mashings at the temperatures respectively of 50° and 70° C.; note in each case the time requisite for saccharification, and the density of the wort. For the different experiments both the mashing liquor and the bath must be regulated to the temperature desired.

286. **Substances inimical to Diastasis.**—Prepare some starch solution and malt extract as in paragraph 283. To a portion of the malt extract add a small quantity of caustic potash, and note the time it takes to saccharify the starch, both starch and malt being used in the same proportions as before. Make similar tests with solutions of sulphuric, tartaric and salicylic acids; lime, copper sulphate, alum, borax, alcohol, and essence of turpentine.

CHAPTER IX.

FERMENTATION.

287. Origin of Term.—When a little of the substance called yeast is added to some wort (i. e., the sweet liquid produced by the infusion of malt with warm water), at a temperature of about 18° C., it induces a most remarkable change. The quiescent liquid after a time becomes filled with bubbles; these rise to the surface and form a scum there; as the action proceeds these bubbles are produced with increased rapidity. Their continuous ascension gives the liquid a seething or boiling appearance, and from this has arisen the application of the term "fermentation" to this peculiar phenomenon; that word being derived from the Latin *ferveo,* I boil. Fermentation results in a disappearance of the maltose present in the wort, together with the production of alcohol and carbon dioxide gas. The former remains in the liquid; the latter rises to the surface and causes the before-mentioned boiling appearance. The carbon dioxide bubbles carry with them to the surface a peculiar sticky "scum"; this substance has received the name of "Yeast," and on being added to a fresh quantity of wort, is capable of setting up fermentation therein. During the fermentation of wort, the quantity of this "scum" produced is many times in excess of that in the first place added to the wort.

288. History of the Views held of the Nature of Fermentation.—The earlier researches and published articles on fermentation regard that change as one of spontaneous decay. Yeast, with which fermentation is associated, was viewed as a peculiar condition which nitrogenous matter assumed during one of the phases of its decomposition. That in this state it was able to set up fermentation in a liquid, which was not at the time fermenting, was noticed as a remarkable property of yeast, which nevertheless was still considered as only nitrogenous matter in a particular stage of chemical change. One of these earlier views ascribed alcoholic fermentation to a vegeto-animal substance which resided in grapes as well as in corn. When the grapes were crushed, and the flour moistened, this fermentative agent commenced to produce active change. The body thus capable of inducing fermentation was termed a "ferment." The next step in investigation of this matter was that of Thénard, who observed that the ferment contained nitrogen, and that in distillation ammonia was yielded; he therefore ascribed an animal nature to the ferment. (It should be explained that the older chemists were in the habit of looking on nitrogenous organic matter as animal, and the non-nitrogenous as vegetable; no reference is intended to the peculiar organic structure of the ferment.) Opinion had settled down to the view that yeast was an immediate principle of plants, when the microscope, which had become such an important factor in scientific research, was brought to bear on the construction of yeast. Leuwenhoeck had, as early as 1680, discovered that yeast consisted of minute granules; but it was only in 1836 that de Latour again called attention to its microsopic structure. It was observed by him that yeast was a mass of little cells, and, further, that these were capable of reproduction by a process of budding. "Yeast, therefore," said the discoverer, "must be an organism which probably, by some effect of its growth, effects the decomposition of sugar into alcohol and carbon dioxide." This newly discovered form of life was, after some discussion, placed among the fungi, a new genus being created for it by Meyen, to which was given the name of Saccharomyces.

This view attracted considerable attention from scientists, and although the basis of that now almost universally accepted, encountered most uncompromising opposition. Prominent among its antagonists was Liebig, who in 1839 argued yeast to be a lifeless albuminous substance, and held that the cause of fermentation is the internal molecular motion which a body, in the course of decomposition, communicates to other matter in which the elements are connected by a very feeble affinity. Said Liebig, "yeast, and in general all animal and vegetable matter in a state of putrefaction, will communicate to other bodies the condition of decomposition in which they are themselves placed; the motion which is given to their own elements by the disturbance of equilibrium is also communicated to the elements of the bodies which come in contact with them." Amplifying this theory, Liebig asserted that the protein bodies decomposed spontaneously, and the molecular disturbance resulting from this decomposition effected also the decomposition of such bodies as sugar, when placed in contact with the decomposing proteins.

For some years, de Latour's, or the vital hypothesis, Liebig's, or the mechanical hypothesis, and other views based on catalytic action, were three contending theories of fermentation.

The next great step was that the whole problem of fermentation received a most careful and exhaustive examination at the hands of Pasteur, who in 1857 gave as his "most decided opinion" that "**the chemical action of fermentation is essentially a correlative phenomenon of a vital act, beginning and ending with it. I think that there is never any alcoholic fermentation without there being at the same time organisation, development, multiplication of globules, or the continued consecutive life of globules already formed.**"

In 1870, Liebig published a long memoir on fermentation, in which he admitted that yeast was a living organism, but still maintained that fermentation was a mechanical act, pointing out that the quantity of sugar decomposed by yeast was out of all proportion to the amount of carbohydrate (cellulose) which the yeast had assimilated. To quote his own words—"Yeast consists of vegetable cells which develop and multiply in a solution containing sugar, and an albuminate, or a substance resulting from an albuminate . . . It is possible that the physiological process stands in no other relation to the process of fermentation than that by means of it a substance is formed in the living cell, which, by an action peculiar to itself—resembling that of emulsin on salicin or amygdalin (enzyme)—determines the decomposition of sugar and other organic molecules." The admission of the physiological action of yeast being even indirectly associated with the decomposition of sugars during fermentation was an enormous concession by Liebig. Writing in 1895, one of the authors summarised the then position in the following terms:—

> "A study of the action of enzymes shows that Liebig's position is partly justified: invertase can be separated from yeast, and afterwards is fully capable of performing its functions of inverting cane-sugar, but such study does not lead us to observe a sufficiently close relationship between enzymic action and alcoholic fermentation as to prove their identity. Still in many respects there is great similarity. At present there is the marked distinction that alcoholic fermentation

is inseparable from life, while enzymosis occurs in the absolute absence of living organisms. **As a result of prolonged research and investigation the vitalistic theory of fermentation is now practically universally accepted.**

"A careful study of the preceding sentence shows, however, that the statement of fermentation being a vitalistic act is not an explanation of fermentation. Granted that fermentation is a concomitant of vitality (i. e., is due in some way to life), there must be some agent through which life acts in producing the chemical change of sugar into alcohol and carbon dioxide. In itself, this change is no more striking than the change of starch, by diastase, into dextrin and maltose; yet we know that diastase, although a direct product of life, is a soluble and absolutely unorganised body. Is there any such unorganised body through which yeast acts when effecting the decomposition of sugar? The answer is—no such substance has as yet been detected, to say nothing of its isolation.

"Hoppe-Seyler and Halliburton incline to the hypothesis that the difference between organised ferment action and that of enzymes is this: an organised ferment is one which does not leave the living cell during the progress of the fermentation; an unorganised ferment, or enzyme, is one which is shed out from the cells, and then exerts its activity. Probably the chemical nature of the ferment is in the two cases the same, or nearly the same.

"So far as we are acquainted with the nature of enzymes, they are either identical with, or closely allied to, the proteins. If fermentation be due to an enzyme-like body within the living cell, that body is of the nature of living proteins—like other proteins they are indiffusible, and consequently are not discoverable outside the cell wall. 'Like all living things, their properties during life are different from those after death; this readily accounts for the fact that, with a few exceptions, they are not discoverable inside the cell wall after the cell has been killed by alcohol. The few exceptions are probably those which are more robust, and withstand the action of alcohol better.' In this way does Halliburton endeavour to explain the difference between organised ferments and enzymes. The explanation, unfortunately, does not cover the whole problem. Even the more robust 'ferments' cannot be said to have life in the ordinary sense of the term when extracted by dilute alcohol, and obtained in a state of perfect solution. Independently of any organism, the enzymes are able to prosecute their functions; but alcoholic fermentation cannot be induced by any substance contained by the yeast cell, unless that cell be living. If the protoplasm of yeast be liberated by crushing the cells, such extracted protoplasm does not cause fermentation. There is little doubt that fermentation does take place within the cell, and is in some way caused by some property of living protein, *but it is an essential that the protein be alive, and a part of a living organism.* This much may be conceded, that probably the living protein acts in a more or less similar manner to an enzyme. In view of this it is interesting to note the agreement rather than the differences between the views promulgated by the illustrious *savants* Liebig and Pasteur; but, after all, there is the broad line of demarcation—enzymosis is independent of living organisms, while 'fermentation is essentially a correlative phenomenon of a vital act, beginning and ending with it.' The discussion of the nature of the vital act producing fermentation does not dispose of the fact of its being vital."

289. Zymase Theory of Fermentation.—In the light of subsequent researches these views must now be considerably modified. In 1897, Buchner made the first announcement of the discovery of zymase, which is referred to and described in paragraph 273. This is an enzyme, secreted within the yeast cell, but which may be extracted from it and apart altogether from the living organism can effect the decomposition of glucose into alcohol and carbon dioxide. Work in this field of investigation was carried still further by the researches of Buchner, Rapp, Albert, Harden, and others, the results of which have been published in a series of papers extending from 1897 to 1905. The net result of such investigation is to confirm the view that zymase is an enzyme, and effects the decomposition of glucose independently of vital functions of the living cell. Of this, a striking proof is afforded by some experiments of Albert, who killed yeast by subjecting it to the action of a mixture of absolute alcohol and ether. The yeast was then dried and still possessed the power of exciting alcoholic fermentation. Consequent on the indiffusibility of the protein contents of the cell, no fermentative enzyme can be extracted from this unbroken yeast by the action of water. But if the cells be broken up, an active extract may be obtained. A dried preparation of zymase has been patented, of which it is said that from 5 to 10 per cent. of it is capable of raising dough. Zymase has no reproductive action, and possesses a fermentative power which is only a minute fraction of that of yeast. It would seem that zymase is destroyed during fermentation almost immediately as formed, so that no accumulated store of the enzyme is found in yeast. Harden believes that zymase alone is incapable of acting on sugar, and that yeast contains in addition another substance which stimulates the zymase into activity. In his opinion neither of these alone sets up fermentation in sugar solutions, but the two acting in conjunction effect the decomposition. In accordance with the zymase theory of fermentation, sugar finds its way by diffusion into the interior of the living cell; it is then changed into glucose by the action of invertase; then the decomposition into alcohol and carbon dioxide is effected by the enzyme zymase secreted by the cell within itself. The zymase is being continually formed and destroyed in the act of inducing fermentation. The discovery of zymase is the discovery of the agent by which yeast effects the decomposition of sugar; but such discovery leads us very little beyond the view of Pasteur that "the chemical action of fermentation is essentially a correlative phenomenon of a vital act," since the zymase is produced as a function of the life of yeast, and is destroyed in the act of fermentation.

290. Definition of Fermentation.—The particular action produced by yeast on wort, and also on the sweet "must," or expressed juice of the grape, was found on investigation to be but one of many chemical actions which are associated with the life, growth, and development of microscopic organisms. Among these may be cited the souring of milk, also of wine into vinegar, and likewise the changes occurring during putrefaction. Consequently the term fermentation is no longer used in its original sense, as signifying a condition resulting in a peculiar seething or boiling, appearance, but is applied to that group of chemical changes which are, in Pasteur's words, "correlative phenomena of vital acts." Subject to the limitations explained in the preceding paragraph, and used in its extended sense, **fermentation may be defined as a generic term applied to that group of chemical changes which are consequent on the life and development of certain minute microscopic organisms.**

In the chapter on the proteins, it was stated that putrefaction is regarded as a species of fermentation: equally, with the conversion of maltose into alcohol by yeast, it is a change induced by living organisms. This of itself is a conclusive answer to Liebig's earlier position, that fermentation is a secondary result of the spontaneous decomposition of proteins, inasmuch as that, in the absence of minute organisms, the decomposition of proteins does not occur: it is consequently not spontaneous, and therefore fermentation cannot be considered as a process dependent on spontaneous decomposition.

291. Modern Theory of Fermentation.—The following is a short statement of this theory. Maltose, proteins, and other fermentable substances do not decompose of themselves, even when subjected to favourable conditions of moisture, warmth, etc., provided that fermenting organisms and their immediate products are rigorously excluded. These, on their introduction, thrive and multiply; taking the nourishment requisite for their development from the substance which is fermented.

A special feature characteristic of fermentation is that the amount of matter consumed and changed into other compounds is excessively great, compared with the size and weight of the consuming organisms; consequently a very few yeast globules decompose very many times their weight of sugar, and produce a relatively large quantity of alcohol and carbon dioxide. No very clear reason has as yet been given for this characteristic of fermentation, but one explanation is that the decomposition of sugar furnishes not only material for the growth and development of cells, but also the heat necessary for the continuance of yeast life. It is this double function of sugar in fermentation which causes the enormous consumption of that compound. Fermentation is thus seen to be like enzymosis in that a small quantity of the active agents induces chemical change in much larger quantities of material; but fermentation goes further, inasmuch as the quantity of fermenting agent itself also increases during its continuance.

In alcoholic fermentation then, yeast, in order to obtain heat and nourishment, attacks glucose or maltose, and excretes or voids carbon dioxide gas, alcohol, and small quantities of other bodies. The assimilative power of yeast is limited to converting the sugar into these substances, which then become, so far as it is concerned, waste products. Other organisms attack the proteins and produce butyric acid and other compounds. Each particular organism has its special products of fermentation.

292. Experimental Basis of Modern Theory.—It is scarcely within the scope of the present work to trace step by step the nature of the various researches which have led to the adoption of the theory just explained. Briefly stated, the first and most important point is that a liquid free from ferment organisms, or their germs does not undergo fermentation. In proof of this point, liquids were placed in flasks or tubes, the necks of which were tightly plugged with cotton wool. The liquids were then boiled for some time; the heat destroyed any organisms that might have been present in the liquids or the wool. As the flasks cooled, the contained steam condensed; and air forced its way through the cotton wool, which acted as a filter and stopped off any germs that might have been floating in the air. Hay and beef infusions, must, wort, urine, and other liquids, on being treated in this manner, may be kept for any length of time without undergoing fermentation or putrefaction. That the resistance to fermentation is due to the absence of fermenting organisms, and not to the liquids having been so changed by boiling as to be unfit for fermentation to proceed, is proved, by adding a small quantity of yeast or other ferment to the sterile liquid, when fermentation sets in and proceeds vigorously. The chemical changes that are produced depend on the nature of the ferment that has been added. Yeast effects the decomposition of sugar into alcohol and carbon dioxide, other ferments cause putrefaction, and result in the typical bodies characteristic of that change. While these actions are progressing, the ferment is found to be developing and multiplying. Further, if the ferment used be pure, one species only of organism is found in the liquid. Within any possible limits of observation no transformation of one ferment into another occurs: each belongs to a distinct and separate race of organisms. This statement does not deny the possibility of the modification of species by means of a natural process of evolution. There is, on the contrary, strong evidence in favour of the gradual evolution of species in course of time.

293. Varieties of Fermentation.—Among the many changes included under this term, the following are of importance in the consideration of our present subject:—Alcoholic fermentation, resulting in the production of alcohol and carbon dioxide; lactic fermentation, in which sugar is converted into lactic acid; acetous fermentation, in which alcohol is transformed into acetic acid; viscous or ropy fermentation, resulting in the production of mannite and different viscous bodies; and putrefactive fermentation, in which butyric acid and a variety of offensive products is formed.

ALCOHOLIC FERMENTATION AND YEAST.

294. The nature of alcoholic fermentation has already been described. For the sake of exactness, Pasteur's definition of it is appended. "Alcoholic fermentation is that which sugar undergoes under the influence of the ferment which bears the name of yeast or barm." When the word "fermentation" is employed without any qualifying adjective, alcoholic fermentation is always understood.

295. Substances susceptible of Alcoholic Fermentation.—Pre-eminent among these are the glucoses, which are directly split up into alcohol and carbon dioxide. Most other sugars may also be fermented; but usually, as in the case of cane-sugar, require first to be hydrolysed to glucose. As already explained, this change is effected, when yeast is added direct to cane-sugar, by the enzyme, invertase; which latter functions independently of the cell itself, and therefore the inversion of the sugar is separate and distinct from fermentation proper. Both diastase and invertase are without action upon maltose; but maltose undergoes inversion into glucose before fermentation by the action of maltase.

Pure yeast is incapable of producing fermentation in either starch paste or dextrin; neither can albuminous bodies, whether of vegetable or animal origin, be fermented.

296. Fermentation viewed as a Chemical Change.—The conversion of glucose into alcohol and carbon dioxide may be represented very simply by the equation—

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Alcohol.}}{2C_2H_5HO} + \underset{\text{Carbon Dioxide.}}{2CO_2}.$$

Taking the action on the glucose as the more simple of the two, the equation given above does not, however, represent the whole of the change, for 100 parts of glucose then would yield—

Alcohol	51.11
Carbon Dioxide	48.89
	100.00

Pasteur carefully collected the whole of the alcohol and carbon dioxide produced by fermentation of a definite weight of glucose, and found that he only obtained—

Alcohol	48.51 per cent.
Carbon Dioxide	46.40 „
	——
	„

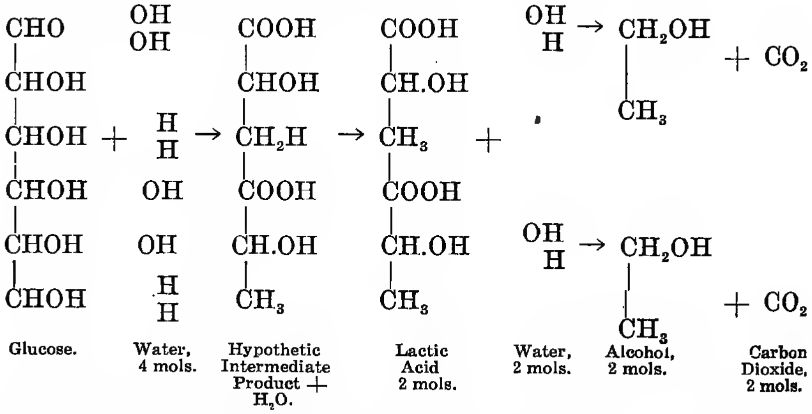
100 — 94.91 = 5.09 parts of glucose not transformed into alcohol and carbon dioxide.

The following bodies occur as subsidiary products—glycerin, succinic acid; propyl, butyl, and amyl alcohols; acetic, lactic, and butyric acids. Of these, the amount of glycerin and succinic acid produced have been found to be—

Glycerin	3.00 per cent.
Succinic Acid	1.13 „
	4.13

This, therefore, leaves but 0.96 per cent. for the various higher alcohols, and the acetic, lactic, and butyric acids; and also for that portion of the sugar that goes to help to build up fresh yeast cells.

Buchner and Meissenheimer point out that acetic and lactic acids are invariably produced in alcoholic fermentation, and under conditions which negative the possibility of the action of bacteria or oxidation by the air. They regard the lactic acid as an intermediate product between the glucose and the alcohol, and suggest the following equation as representing the change which occurs:—



Monoyer proposes the following equation as showing the production of glycerin and succinic acid from glucose—

$$\underset{\text{Glucose.}}{4C_6H_{12}O_6} + \underset{\text{Water.}}{3H_2O} = \underset{\text{Succinic Acid.}}{H_2C_4H_4O_4} + \underset{\text{Glycerin.}}{6C_3H_5(HO)_3} + \underset{\text{Carbon Dioxide.}}{2CO_2} + \underset{\text{Oxygen.}}{O.}$$

No free oxygen is, however, detected in fermentation; any that may be produced during the decomposition is probably used up by the yeast cells for purposes of respiration.

Pasteur claims that the glycerin and succinic acid, as well as the alcohol and carbon dioxide, are normal products of alcoholic fermentation; and further, that these bodies are produced from the sugar, and not from the ferment. He also shows that a portion of the sugar goes to help to build up the yeast globules. The quantities of glycerin and succinic acid produced are not constant, but vary with the conditions under which fermentation proceeds; when the action is slow the proportion of glycerin and succinic acid to alcohol is higher than with brisk and active fermentation.

Brefeld, however, argues that glycerin and succinic acid are not products of alcoholic fermentation proper, but rather are pathological products arising out of the death of the yeast cells. The same view is advanced in a more modernly expressed opinion that these bodies are due to the destructive metabolism* of the cells.

A small proportion of the carbohydrate, amounting to about 1 per cent., is assimilated by the yeast and employed in its constructive metabolism, being transformed into cellulose and fats.

Jörgensen states that during fermentation by the pressed juice of yeast, i.e. by the separated zymase, glycerin is produced to the extent of from 3 to 8 per cent. of the fermented sugar, and is derived from the sugar. On the other hand, no succinic acid is formed. Acetic acid is produced in minute quantities, but somewhat more than in the fermentation with the living cell. This is probably due to the action of a special enzyme. (*Micro-organisms and Fermentation,* Fourth Edition.)

297. Chemical Composition of Yeast.—When yeast has been washed carefully so as to free it as far as possible from foreign matters, and then dried, it is found to have, according to Schlossberger, the following composition—

	Surface Yeast.	Sedimentary Yeast.
Carbon	48.7	46.4
Hydrogen	6.4	6.2
Nitrogen	11.8	9.5
Oxygen	30.7	34.5
Ash (mineral matter)	2.4	3.4
	100.0	100.0

In addition to the above a number of other analyses might be quoted, showing that yeast is a body of somewhat variable composition; meanwhile attention is directed to the fact that yeast collected from the bottom of the fermenting liquid contains less nitrogen and carbon than does surface yeast.

Various attempts have been made to separate yeast into its proximate principles, and estimate these: as a result it may be stated that yeast contains one or more bodies of the protein type. There are in addition, also present, cellulose and fatty matters. Payen gives the following as the result of an analysis of moisture-free yeast:—

Nitrogenous Matter	62.73
Cellulose (envelopes)	22.37
Fatty Matters	2.10
Mineral ,,	5.80

Nægeli states that the proximate constituents of a sample of yeast examined by him were as follows. The yeast was a sedimentary one, containing 8 per cent. of nitrogen:—

Cellulose, Gum, and Cell Membrane	37	per cent.
Proteins	45	,,
Peptones	2	,,
Fat	5	,,
Extractives (Leucine, Cholesterin, Dextrin, Glycerin, Succinic Acid)	4	,,
Ash	7	,,

---

* For an explanation of metabolism refer to Chapter XIII, par. 408.

A sample of distiller's compressed yeast examined by one of the authors gave the following results on analysis:—

Proteins	12.67
Fat	0.80
Mineral Matter	2.05
Water	73.80
Cellulose, etc. (by difference)	10.68
	100.00

The mineral matter of yeast is of great importance, and has been made the subject of careful analysis by Mitscherlich and others. The following table gives the composition of the ash of surface and sedimentary yeasts by Mitscherlich, and of the surface yeast of pale ale by Bull—

	Surface Y.	Sedimentary Y.	Surface Y. of Pale Ale.
	Mitscherlich.		
Phosphoric Acid, P_2O_5	53.9	59.4	54.7
Potash, K_2O	39.8	28.3	35.2
Soda, Na_2O	—	—	0.5
Magnesia, MgO	6.0	8.1	4.1
Lime, CaO	1.0	4.3	4.5
Silica, SiO_2	traces	—	—
Iron Oxide, Fe_2O_3	—	—	0.6
Sulphuric Acid, SO_3	—	—	—
Hydrochloric Acid, HCl	—	—	0.1

Yeast ash is therefore composed principally of phosphoric acid and potash: attention is directed to the similarity in composition between the ash of yeast and that of wheat. The above acids and bases probably exist in combination as the following salts:—

	Surf. Y.	Sed. Y.
Potassium Phosphates	81.6	67.8
Magnesium Phosphate, $Mg_3(PO_4)_2$	16.8	22.6
Calcium Phosphate, $Ca_3(PO_4)_2$	2.3	9.7

The potassium phosphate must be looked on as a mixture of the dihydric phosphate, KH_2PO_4, and the monohydric phosphate, K_2HPO_4. The former of these phosphates contains 94 by weight of K_2O to 142 of P_2O_5; the latter contains 188 of K_2O to 142 of P_2O_5. The weight of K_2O in the surface yeast ash is between that required to produce either of these two potassium phosphates. The composition of the potassium phosphate of the sedimentary yeast ash nearly agrees with the formula, KH_2PO_4.

298. Yeast as an Organism.—Viewed as an organism, yeast may be said to be a plant of an exceedingly elementary structure; it is in fact one of the simplest plants known. In very minute forms of life it is difficult to distinguish animals and vegetables from each other, for with almost any definition that may be selected, one or two species wander over the border line. One of the most marked differences between the higher plants and animals is, that the former are able to derive their sustenance from inorganic compounds, their carbon from carbon dioxide, and their nitrogen from ammonia. Animals, on the contrary, can make no use of carbon or nitrogen for the purpose of building up their tissues, unless these bodies are presented to them in the form of organic compounds. Hence, in the economy of nature, it will be found that while plants live and develop, as before stated, by the assimilation of the elements of carbon dioxide and ammonia, animals subsist either on vegetable substances, or on the bodies of other animals. Yeast is unable to assimilate carbon from inorganic sources, but being able to derive its nitrogenous nutriment from inorganic bodies, is placed in the vegetable kingdom. The chemical changes produced during the growth of the higher plants result in the building up of complex compounds from very simple ones: in the animal, complex bodies are required as nourishment, and are broken down into simpler bodies. The complexity here referred to is that which may be measured by the number of atoms in the molecule of the body; thus, water is a very simple compound, while starch has a most complex molecular structure. The chemical operations of plant-life may be summed up as consisting of synthesis; those of animal existence as analysis. In order to effect the synthesis of plant compounds from the substances at the disposal of vegetables, force is required; this they usually obtain in the form of heat from the sun. The act of growth of a plant means, therefore, a continual absorption of heat. On the other hand, animals, in taking complex bodies and breaking them down into simpler ones, liberate heat; consequently, one result of animal life is that heat is continuously being evolved. Yeast, in this particular, partakes both of the nature of an animal and of a plant. Its nitrogen may be obtained from inorganic sources, but is more usually derived from suitable protein matter, such as peptones. On the other hand, the carbon of yeast is taken from sugar with the breaking down of that body into simpler compounds, and the consequent liberation of heat; therefore during fermentation the temperature of the liquid rises considerably. From a chemical standpoint, yeast combines in itself the vegetable functions of synthesis with the animal functions of analysis.

299. Botanic Position of Yeast.—This organism belongs to the family of Fungi.

Fungi.—The fungi are those plants which are destitute of chlorophyll (the ordinary green colouring matter of grass, etc.). They reproduce by buds and spores.

Spores.—Spores are a variety of cell, and in all fungi the spores are similar in essential points to the yeast cell; notwithstanding that they may vary considerably in appearance and details of structure.

Hyphae.—The spore, on being sown in a suitable medium for its growth, throws out a long delicate stem of tubular structure, termed a "hypha." A group of these hyphæ constitute the fungus.

Mycelium.—One of the best typical examples of a fungus is the common green mould found on old boots, bread, jam, etc. This has received the name *Penicillium glaucum.* On examining a specimen of such mould from the top of a pot of jam for instance, its base is found to consist of an interlaced growth of hyphæ, forming a more or less compact web or skin on the jam. This layer of intermingled hyphæ is termed the "mycelium." From its upper surface a number of hyphæ project into the air, each bearing a quantity of very fine green powder, these are termed "aerial hyphæ." On the lower surface again, other hyphæ grow down root-like into the liquid, which supports the mould; these are the "submerged hyphæ."

Conidia.—Some of the aerial hyphæ terminate in short branches, each of which is divided into a series of rounded spores which are only loosely attached to the hyphæ, and so may easily be shaken off; these spores are termed "conidia." Each separate conidium, if sown in a suitable liquid, develops a young fungus, which in its turn rapidly multiplies.

Sporangia.—Some of the fungi, as for instance that known as *Mucor mucedo,* have their hyphae terminated in rounded heads; each of these is

300. Varieties of Yeast.—The yeast fungi constitute the genus *Saccharomyces;* they are so named because they mostly live in saccharine solutions, converting the sugar present into alcohol. The *saccharomyces* have no mycelium, and in common with the other fungi reproduce by buds and spores. The genus *saccharomyces* comprises several species, a detailed description of which will subsequently be given.

301. Nature of Yeast Cells.—The yeast organism consists of cells, mostly round, or slightly oval, from 8 to 9 μ in diameter; the cells may occur either singly or grouped together as colonies. It is impossible to obtain any real knowledge of the physical structure of yeast without a careful and systematic personal examination by the microscope; it has been thought well, therefore, to arrange the following description in such a form as to constitute a guide to actual yeast examination.

1. Take either a little brewers' yeast, or bakers' compressed distillers' yeast, and mix with some water until a milky fluid is produced. By means of a pointed glass rod, take a small drop of this fluid and place it on a clean microscopic slide, and gently cover with a cover-glass. Arrange the microscope in a vertical position, and proceed to examine the yeast by means of a fairly high power (1/8 objective). Notice that the yeast consists of cells, of which measure a few by means of the eye-piece micrometer, and observe that their dimensions agree with those just given. Each cell consists of a distinct wall or envelope, containing, within, a mass of more or less gelatinous matter devoid of organic structure. The interior substance is named "protoplasm"; this term being applied to that ultimate form of organic matter of which the cells of animals and plants are composed. The protoplasm of the yeast cell is not homogeneous, but is always more or less distinctly granular. Run in magenta solution under the cover-glass. (This is readily done by placing a drop of the solution in contact with one side of the cover-glass, and placing a strip of blotting-paper on the other.) Notice that the sac or envelope remains uncoloured, while the protoplasm stains comparatively deeply; the vacuoles are unstained. One or more circular spots can usually be seen in yeast cells as obtained from a brewery; these are caused by the gelatinous matter moving toward the sides of the cell, and leaving a comparatively empty space, containing only watery cell-sap; hence these spots are termed vacuoles. A specimen of yeast is shown in Figure 9.

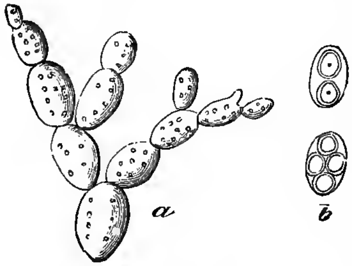


FIG. 9.—Saccharomyces Cerevisiœ. *a*, a bud colony; *b*, two spore-forming cells (after Lurssen).

2. Remove the slide from the microscope, and burst a few of the cells by placing some folds of blotting-paper on the cover-glass, and then pressing sharply with the end of a pencil or rounded glass rod. Again examine under the microscope, note the empty sacs and the extruded protoplasm, which does not readily mix with the water.

If practicable, try this experiment with yeast of various ages; very old yeast cells break more easily, and the protoplasm is more fluid, and takes the colour more readily. By using the magenta stain in a dilute form, old and dead cells may be differentiated from those which are healthy and vigorous—the latter remain unstained, or take up the stain very slightly, while dead cells readily and quickly acquire a magenta hue.

3. Take six clean cover-glasses and coat one side of each with a thin layer of yeast, by painting on the mixture of yeast and water by means of a camel's hair brush, and set aside until thoroughly dry. The yeast adheres firmly to the glass, showing that the outside of the cell-walls is mucilaginous in character.

4. Add a drop of solution of iodine in potassium iodide to one of these covers, let it stand five minutes, and then wash slightly in water, and mount the cover-glass, yeast side downward, on a glass slide. The cell-wall stains slightly, and the protoplasm becomes dark brown; but no blue colour is produced; starch therefore is absent. As the cell envelope is continuous, containing no apertures, the iodine solution must have passed through its substance.

5. Similarly treat another cover preparation with iodine, and then, without washing, add one or two drops of 70 per cent. sulphuric acid. The cell-contents acquire a deeper brown stain, and the cell walls become brownish yellow, but do not show any blue colouration.

The cellulose of the walls of the cells of most higher plants acquire a blue colour with this treatment, showing the presence of a cellulose allied to that of starch, but the cellulose of yeast, and of fungi generally, is devoid of this property.

6. Treat the yeast on another cover-glass with solution of potash. The protoplasm is dissolved, leaving nothing to be seen but empty cell-walls.

7. Treat another cover-glass preparation with a solution of osmic acid. Note that small, sharply defined, dark coloured bodies are seen. Jörgensen regards these as cell-nuclei of the same nature as those generally observed in the majority of plants without this treatment.

8. Break down a little yeast with water, and focus under the microscope, so as to observe distinctly the small bright granules of fat within the protoplasm of the cells. Put a piece of blotting-paper on one side of the cover-glass, and run in at the other a few drops of ether from a fine pipette—the fat granules dissolve and disappear.

302. Life History.—On examining under a microscope a sample of skimmed yeast, as obtained from the brewer, it is found to consist either of single cells, or cells joined together in pairs. Such yeast having usually remained quiescent for some time, the cells rarely occur in large groups because, with standing, they tend to separate from each other. The granulations in the protoplasm, and also the vacuoles, should be visible. On placing a very small quantity of this yeast in a suitable liquid for its growth, as malt wort, at a temperature of about 30° C. (86° F.), the cells, which at first were somewhat shrunken and filled throughout with granular matter, increase in size from absorption of the liquid in which they are placed. At the same time the granulations becomes less distinct, and the whole cell assumes a more transparent and distended appearance.

To observe this effect, mount a few cells on a microscopic slide with warm malt wort, and keep under observation with the microscope. After a time the round yeast cells become slightly elongated through the formation of a small protuberance at one end; this grows more marked, until shortly a neck is formed by a contraction of the cell wall. But still, careful examination shows that there is a distinct opening through this neck, the contents of the smaller portion being continuous with those of the cell. As the growth continues, the strangulation at the neck proceeds until the cell wall completely shuts off the protuberance, which then constitutes a new or daughter cell, attached to the parent. This operation is known as "budding." The one parent cell is capable of giving off several buds in succession; but after a time its reproductive energy is exhausted, and the cell breaks up. These daughter cells in their turn give rise to other cells, and so the multiplication of yeast globules proceeds with remarkable rapidity.

Pasteur states that on one occasion he watched two cells for two hours; during that time they had multiplied by budding into eight, including the original pair of cells. At this stage, buds of every size may be seen attached to the parent cells; some are so small as to be scarcely visible, while other are nearly as large as the parents.

With the progress of this growth and development, sugar is being decomposed, the liquid becomes alcoholic, and its specific gravity diminishes. The brewer terms this change "attenuation," or a becoming thinner. Another reason for the use of this name is that the liquid becomes less viscous, from the conversion of the sirupy solution of maltose into the highly mobile liquid, alcohol. Simultaneously with the production of alcohol, carbon dioxide gas is evolved; this rapidly rises to the surface, and carries up with it the yeast cells, which float on the top of the fermenting wort. Yeast now skimmed off is found to consist of colonies of some scores of cells linked together; the majority of these are clear and almost transparent. Usually in the middle of each such group the old or parent cell can be recognised by its darker contour and comparatively exhausted appearance. As the quantity of sugar in the liquid becomes less, the fermentation slackens, and finally ceases. If the cells then be again examined, under the microscope, they will be found to have a firmer outline, and their contents will be more granular. In what may be termed old age of the yeast cell, the walls become abnormally thick, and the granulations very dense. The yeast, on being removed from the fermenting tun, is usually set aside in store vats; on standing, it gradually assumes the appearance described as that of the yeast used for "pitching" or starting the fermentation. The quantity of yeast thus obtained is considerably in excess of that first added to the malt wort.

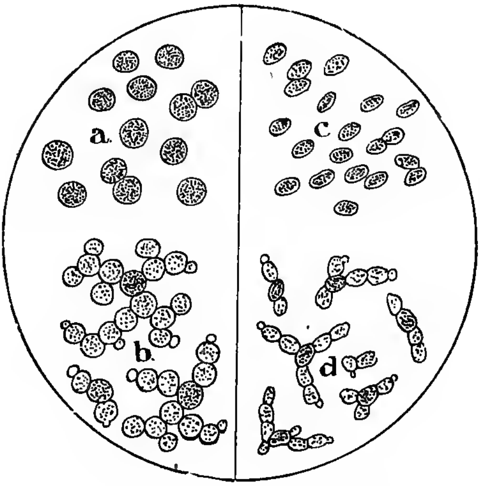


FIG. 10.—Saccharomyces Cerevisiœ.
a, High Yeast, at rest; *b*, High Yeast, actively budding; *c*, Low Yeast, at rest; *d*, Low Yeast, actively budding.

In the moist state, yeast decomposes quickly; hence if the store be kept for any length of time, the cells rapidly alter in character. The walls become soft, thin, and weak, and the interior protoplasm changes from its normal granular gelatinous condition to a watery consistency. After a time, if viewed with a high power, a distinct "Brownian" movement is seen of particles suspended in the contents of the cell. The particles may very possibly consist of minute fragments of cellulose from the envelopes. After a time the walls also break down and all traces of the yeast organism disappear. The normal bodies produced by the decomposition of nitrogenous and protein bodies may now be detected in the liquid: putrefaction rapidly follows, with the production of a most offensive odour. Such is in broad outlines the life history of a yeast cell, when sown under normal conditions in malt wort.

Distillers' yeast putrefies much more readily than does that of the beer brewer: the hops used in the latter act as an antiseptic, and the yeast putrefies much less rapidly. Evidence of this is afforded in the method employed for the preparation of invertase from brewers' yeast.

High yeast produces a beer having a special and characteristic flavour, which distinguishes it at once from beer brewed with low yeast.

303. Influence of Temperature on Yeast Growth.—The temperature most favourable to the growth of yeast is from 25° C. to 35° C. (77° and 95° F.) Between these points yeast flourishes and grows well; at temperatures lower than 25° growth proceeds, but not so rapidly. At a temperature of about 9° C. (49.6° F.), the action of yeast is arrested; the vitality, however, of the cell is only suspended, not destroyed, for with a higher temperature it again acquires the power of inducing fermentation. Actual freezing does not destroy yeast, provided the cells do not get mechanically ruptured or injured. Above 35° C., the effect of heat is to weaken the action of yeast, until at a temperature of about 60° C. (140° F.), being that at which protein principles begin to coagulate, the yeast is destroyed. This applies to moist yeast. When dry, the cells are able to stand higher temperatures than when suffused with water; thus, dried yeast has been heated to 100° C. without destroying its vitality.

Although a temperature of from 25° to 35° C. conduces to the rapid growth of yeast, yet there are other circumstances which render it advisable to conduct actual brewing operations at a much lower temperature. In English breweries, a pitching temperature of about from 18° to 19° C. (65° F.) is commonly employed: during the fermentation the heat rises to from 21° to 22° C. (72° F.).

Faulkner states that a tun of pale ale, containing 200 barrels of 36 gallons, on being pitched with 600 lbs. of yeast at 14.5° C. (58.1° F.) had sufficiently attenuated in 46 hours, during which time the temperature had risen to 22.2° C. (72° F.).

304. Substances Requisite for the Nutriment of Yeast.—It has several times been stated that sugar is required by yeast during its growth: as yeast cells likewise contain nitrogenous matter, and also certain inorganic constituents, it is evident that nitrogen in some form, and also the requisite mineral salts, must be supplied to the growing yeast. Summing these up, yeast requires for its growth, sugar, nitrogenous compounds, and appropriate inorganic matter.

305. Saccharine Matters.—These occupy the first and paramount position, as being absolutely necessary for the production of alcoholic fermentation. Pure yeast sown in a pure sugar solution causes it to ferment; but without the sugar neither alcohol is produced, nor carbon dioxide evolved. Malt wort, grape juice or "must," and dough, all ferment on the addition of yeast, because they all contain sugar. **"It is necessary indeed that sugar be present; for if we abstracted by some means or other from the must or dough all the sugar contained in it, [1][and also all substances capable, by the addition of yeast to flour, of being converted into sugar], without touching the other constituents, the addition of yeast would produce no gas. Everything would remain**

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[1] The clause in brackets, [ ], is inserted by the authors.

quiet until the moment when signs of a more or less advanced putrefaction showed themselves." (Pasteur). It should be mentioned that yeast is also capable of inducing definite chemical changes in a few other bodies: among these is malic acid, which is broken up into succinic and acetic acids, carbon dioxide, and water. It is also stated that yeast decomposes glycerin into propionic and acetic acids; this change has been denied by Roos and Brown. As neither malic acid nor glycerin (in the free state) occur as constituents of flour, their fermentation lies altogether outside the scope of the present work.

The glucoses, or sugars of the $C_6H_{12}O_6$ group, are the only sugars capable of direct fermentation; of these, glucose or dextrose is more readily decomposed by yeast than is fructose. The two being together in the same solution, the fructose remains unacted on until the disappearance of the whole of the glucose. Certain other sugars are capable of indirect fermentation by yeast; among these are cane-sugar, which first, however, requires to be hydrolysed to glucose by the action of the invertase or soluble diastatic body secreted by the yeast cell. As already explained, this preliminary diastasis can be effected by yeast water, that is, water with which yeast has been shaken up, and then filtered in order to remove the whole of the yeast cells; such yeast water is, of itself, incapable of setting up alcoholic fermentation.

Yeast causes certain effects, of which it is difficult to say whether they are absolutely correlatives of vital acts, as an organism, or merely results of diastasis. For practical purposes, it matters little to which of these two classes of chemical action any specific change produced by yeast belongs; in such cases it is the action of yeast, as a whole, that is of importance.

Sugar of milk is incapable of fermentation by yeast. Yeast alone is also unable to ferment either starch paste or dextrin: these bodies require some more powerful agent for their diastasis, such as malt extract. As mentioned in Chapter VIII., yeast, indirectly through its action on the proteins of barley or wheaten flour, transforms starch paste into dextrin and maltose, after which the yeast induces fermentation. Consequently, the two, yeast and proteins, in conjunction, are capable of effecting changes which neither can separately produce.

It almost goes without saying that water is necessary for the development of yeast, so requisite is it that saccharine solutions containing over 35 per cent. of sugar are incapable of fermentation. Such a solution, by outward osmose through the cell wall, deprives the yeast of its normal proportion of water as a constituent.

306. Nitrogenous Nutriment.—Yeast is capable of utilising, during its growth, the nitrogen of ammoniacal salts (but not that of the acid radical of nitrates); thus, a solution of pure sugar, mixed with either ammonium tartrate or nitrate, and certain non-nitrogenous inorganic salts, permits a healthy development of yeast. With the multiplication of the yeast cells, the amount of protein matters present increases; therefore, by the action of yeast, the ammonium compounds are transformed into protein bodies. Although yeast thus acts on ammonium salts, organic nitrogenous compounds form a more suitable nutriment; among such substances, the soluble proteins of yeast itself are especially seized on by yeast. Consequently, always supposing the presence of the inorganic salts required by yeast, yeast water and sugar form an admirable medium for its growth and development; so, too, do natural saccharine juices, as "must," the juice of apples, pears, etc. In addition to these, malt infusion must be mentioned.

Albumin, whether from the white of egg or vegetable albumin, is entirely unfit for the nourishment of yeast. This fact is stated with force by Pasteur, whose opinion is confirmed by that of Mayer, who ascribes the inactivity of albumin, casein, and other similar bodies, to their highly colloid nature. The solution molecules of soluble proteins of malt have such an appreciable volume, that filtration of the solution through a thin porous earthenware diaphragm under slight pressure is sufficient to prevent these bodies from passing through into the filtrate (Brown and Heron). It may then be readily understood that yeast cell walls are impermeable to protein bodies. The compounds produced by digestion of albumin and its congeners, the peptones, are much more diffusible, and are eminently suited for affording the requisite nitrogenous nutriment to yeast. Pepsin itself forms an admirable yeast food. Schützenberger considers it probable that must, malt wort, and yeast water owe their power of nourishing the cells of yeast, not to the protein bodies, but to certain of their constituents that are analogous to the peptones, and which have the property by osmose of passing through the cell walls.

307. Mineral Matters necessary for the Growth of Yeast.—For his experiments on yeast, Pasteur used yeast ash as the source of his mineral matter. It is obvious that this substance may be replaced by an artificial mixture of the salts contained therein. A reference to Mitscherlich's analyses of yeast ash shows that the principal ingredient is potassium phosphate; together with this, there is magnesium phosphate and small quantities of phosphate of calcium. Pasteur finds, when an unweighable quantity of yeast is sown in a solution of pure sugar and ammonium tartrate, that development of cells and fermentation do not take place; the addition of yeast ash enables both to occur. Mayer endeavoured further to ascertain what salts are, in particular, necessary among those present in the ash. Potassium phosphate is absolutely indispensable; neither sodium nor calcium phosphates are competent to replace it. Magnesia is also of great value, if not indispensable, to the development of yeast; this base may be supplied either as sulphate or phosphate. Lime seems not to be absolutely necessary to yeast growth.

308. Insufficiency of either Sugar or Nitrogenous Matter only for the Nutriment of Yeast.—Yeast is incapable of healthy development in solutions of sugar alone. A limited growth occurs when the quantity of yeast added is considerable, because, by a species of cannibalism, the healthier and stronger cells survive and develop to some extent by feeding on the nitrogenous and mineral matters obtained from the others. Necessarily, such growth must soon stop. Yeast was stated by Pasteur to multiply in a nitrogenous liquid, such as yeast water, "even when there was not a trace of sugar present, provided always that atmospheric oxygen is present in large quantities." Yeast finds air to be under these conditions an absolute necessity. Without it no development proceeds, nor is there any but the slightest trace of alcohol found; carbon dioxide gas is evolved, being formed by direct carbonisation of oxygen derived from the air. But, for this change, it must be remembered that air is a necessity. Assuming the correctness of Pasteur's views as to the growth of yeast by the assimilation of atmospheric oxygen, and expiration of carbon dioxide, it is necessary to remember that the conversion of oxygen into carbon dioxide gas results in no change of volume; this is clearly seen by reference to the molecular equation—

$$\underset{\text{Carbon}}{C} + \underset{\text{Oxygen}}{O_2} = \underset{\text{Carbon Dioxide}}{CO_2}.$$

Under ordinary conditions of fermentation, albumin does not evolve alcohol or carbon dioxide gas. Neither does pepsin when similarly treated, although this body is well adapted as a nitrogenous food for yeast. Albumin is also unacted on when its solution is first of all mixed with a 2½ per cent. solution of sodium chloride.

309. **Behaviour of Free Oxygen on Yeast.**—As stated in the preceding paragraph, Pasteur regarded atmospheric oxygen as capable of acting as a substitute for sugar in the nutriment of yeast, and accordingly he examined very carefully the general behaviour of free oxygen and yeast to each other. In consequence, he developed the following theory of fermentation, which for some time was generally accepted.

Pasteur states, as a result of experiment, that yeast grows better in shallow than in deep vessels. As a result of some determinations made, in which one sample of yeast and a saccharine solution were kept in an air-free flask, and another in a shallow vessel, by which it was freely exposed to the atmosphere, he finds that the proportion of yeast produced to the sugar consumed was much greater in the latter than in the former instance. By dint of most careful experiment he further finds, while a fermentable liquid may be made to ferment out of contact with air, yet in order that it shall do so it is essential that young and vigorous yeast cells shall be employed. With older yeast the fermentation proceeds more slowly, and with the production of mal-shaped cells, while a yeast still older is absolutely incapable of reproduction in a liquid containing no free oxygen. This is not due to the yeast being dead, for on aerating the liquid, either with atmospheric air or oxygen, fermentation proceeds apace. Pasteur therefore concluded that under favourable circumstances yeast functions as a fungus; that is, it lives by direct absorption of oxygen from the air, and the return of carbon dioxide gas. He consequently assumed the following relationship between its life in free oxygen and its life when submerged in a sugar solution—Let some yeast be sown in a sample of malt wort, containing as much oxygen as it can possibly dissolve; the yeast starts active growth, and rapidly removes all the free oxygen from the liquid, *after* which it commences to attack the sugar. During this time, yeast will be living not as a ferment but as a fungus, namely, by direct absorption of oxygen. Could each yeast cell be supplied with all the oxygen it requires in the free form, it is probable that it would not exert the slightest fermentative action; it would, at the same time, grow and reproduce active healthy cells with great rapidity. As soon as the whole of the air is exhausted, the yeast attacks the sugar, and obtains its oxygen by the decomposition of that compound, and ordinary fermentation proceeds. Consequently, yeast must be viewed as being capable of two distinct modes of existence, in free oxygen as a fungus; when submerged in a saccharine solution, as a ferment. Of the two the fungus life is the easiest; that is, yeast can perform its vital functions more readily when it obtains its oxygen in the free state than when it has for that purpose to effect the decomposition of large quantities of sugar. If yeast be grown continuously in saccharine solutions, under conditions which result in the rigid exclusion of air, fermentation becomes more and more sluggish: the conditions of life are in fact more severe than the yeast can stand, the struggle for existence is too acute, and its vitality succumbs. But if a sample of fermenting wort be taken at a time when, although the sugar is far from exhausted, the fermentation has become sluggish, and then thoroughly aerated by some means which shall bring it into full contact with air, a remarkable change ensues. At first the fermentation slackens, but the rate of growth of yeast increases; this is due to its living as a fungus on the dissolved free oxygen. During this time it exerts little action as a ferment, but grows and accumulates vital energy. After a while, the fermentation proceeds much more vigorously than before the aeration; this is a necessary result of the renewed energy and vitality of the yeast cells.

That oxygen is capable of acting in some way as a stimulant to fermentation was known to brewers long before the announcement of this theory by Pasteur, as they had found that by "rousing" (stirring) tuns of wort that were fermenting sluggishly, the fermentation was invigorated. The agitation following from this rousing aerated the wort.

To borrow his own words, Pasteur summed up his theory of fermentation in the following terms:—"Fermentation by yeast is the direct consequence of the processes of nutrition, assimilation, and life, when these are carried on without the agency of free oxygen. . . . Fermentation by means of yeast appears, therefore, to be essentially connected with the property possessed by this minute cellular plant of performing its respiratory functions, somehow or other, with oxygen existing combined in sugar. Its fermentative power varies considerably between two limits, fixed by the greatest and least possible access to free oxygen which the plant has in the process of nutrition. If we supply it with a sufficient quantity of free oxygen for the necessities of life, nutrition, and respiratory combustions, in other words, if we cause it to live after the manner of a mould, properly so called, it ceases to be a ferment; that is, the ratio between the weight of the plant developed and that of the sugar decomposed, which forms its principal food, is similar in amount to that in the case of fungi. On the other hand, if we deprive the yeast of air entirely, or cause it to develop in a saccharine medium deprived of free oxygen, it will multiply just as if air were present, although with less activity, and under these circumstances its fermentative character will be most marked; under these circumstances, moreover, we shall find the greatest disproportion, all other conditions being the same, between the weight of yeast formed and the weight of sugar decomposed. Lastly, if free oxygen occur in varying quantities, the ferment power of the yeast may pass through all the degrees comprehended between the two extreme limits of which we have spoken." According to this view, fermentation is a starvation phenomenon, brought about by the want of free oxygen during the life of yeast cells in a fermentable liquid.

310. Brown on Influence of Oxygen on Fermentation.—In 1892, Adrian J. Brown contributed an important paper on this subject to the *Journal of the Chemical Society*, which paper necessitates a reconsideration of the theory of fermentation. In his experiments, Brown employed the method of *counting* the yeast cells in his various solutions, by means of the hæmatimeter, instead of *weighing* the yeast, as had been done by Pasteur in his various researches. This method of working has the advantage that the results are capable of being referred to the amount of effect being produced by the action of an unit cell.

Brown's first conclusions were that "when any fermentable nutritive solution, such as malt wort, or a solution of dextrose in yeast water, is inoculated with a high fermentation yeast, and kept at a temperature favourable to yeast growth, the cells reproduce themselves rapidly for a time, and then their reproduction ceases, and that the fermentation of the solution may still be carried on by the continued life of the cells already formed.'' Further, he found that with the same liquid, under the same conditions, the cells increase to about the same maximum, no matter how the number of cells introduced to start the fermentation may vary. In support of this view, the following experiment is quoted—Two flasks, A and B, were taken, and in each 150 c.c. of the *same* malt wort was placed, and then a different amount of the same yeast added to each. The contents of the flasks were thoroughly agitated, and the cells counted by the hæmatimeter. (The standard volume of the instrument employed was 1/4000 of a cubic millimetre, called hereafter ''Standard Volume.'') The flasks A and B contained respectively 0.93 and 7.44 cells per standard volume. The flasks were kept at 25° C. until fermentation had completely ceased, when the cells were again counted. In flask A the number of cells per standard volume had increased from 0.93 to 25.24; whereas in flask B the increase was from 7.44 to 27.08. The rate of increase differed widely, but the ultimate number of cells produced was approximately the same. From these and a number of other similar experiments, the conclusion is drawn that in such fermentations the number of yeast cells increases to some fixed maximum, irrespective of the number originally added to induce fermentation.

The next point was to experiment by adding more cells than this maximum number, two similar flasks of malt wort were respectively seeded with 6.0 and 70.8 cells of yeast per standard volume. Fermentation was allowed to proceed, and, at its close, in No. 1 flask the cells had increased from 6.0 to 24.9, while in No. 2 they had decreased from 70.8 to 68.2 cells. In this experiment 24.9 cells may be regarded as the maximum number that the wort used would grow, consequently with No. 2 flask there is no increase. Brown regards the actual diminution as due to the death and disintegration of some of the cells. In the second flask as well as the first, fermentation proceeded with great rapidity. Other experiments made yielded the same results; therefore, if a nutritive liquid be seeded with a considerably larger number of yeast cells than the maximum number it is capable of producing by reproduction, fermentation proceeds, and a method is afforded of studying fermentation without multiplication of yeast cells. Having a constant quantity of yeast, throughout the experiment, evidently eliminates many disturbing factors present when the quantity of yeast is variable.

Brown in the first place applied this method to the investigation of the action of oxygen on yeast. A malt wort of 1065 sp. gr. was taken, and yeast added to the extent of 85 cells per standard volume; 120 c.c. of this solution were poured into a flask, A, so as to nearly fill it; its mouth was then stopped in such a manner as to permit the escape of carbon dioxide gas, but to prevent air gaining access to the solution; 120 c.c. of the same solution were also placed in another flask, B, of about 1500 c.c. capacity, so that it simply formed a thin layer on the bottom; this flask was so arranged as to permit a current of air being drawn through the liquid. Both flasks were thus similar, except that from the one air was excluded, while the contents of the other were subjected to abundant aeration. The fermentation was conducted at 19°, and, after the end of three hours, arrested by the addition of salicylic acid. The liquids were distilled, and the amount of alcohol produced estimated from the specific gravity of the distillate. In A flask, without aeration, 3.35 grams of alcohol had been formed; while in B, through which a continuous current of air had been drawn, the alcohol amounted to 3.56 grams. The number of yeast cells remained unaltered at the close of the experiment, but slight attempts at abortive budding were observable, particularly in the aerated flask. Another experiment was tried, in which the fermentable medium was a solution of glucose in yeast-water, which was seeded with 90 cells per standard volume. At the end of three hours, fermentation was arrested, and the residual sugar in the solutions determined polarimetrically. In A (unaerated) 1.96 grams of glucose had been fermented; while in B (aerated) the quantity of fermented glucose was 2.32 grams. In neither case was there any sign of budding or enlargement of the cells.

In order to meet the objection that the mechanical effect of aeration might stimulate the action of the cells in the B flasks, the following pairs of experiments were made in which the A flasks were subjected to the action of currents of carbon dioxide and hydrogen respectively, and at about the same rates as the air through the B flasks. The following were the results:—

"A" flask, with carbon dioxide passed,	3.99	grams of glucose fermented.
Companion B flask, with air passed,	4.28	,, ,, ,,
"A" flask, with hydrogen passed,	2.26	,, ,, ,,
Companion B flask, with air passed,	2.45	,, ,, ,,

In every case the most work is done in the presence of oxygen.

In all the preceding experiments, as the consequence of the employment of large quantities of yeast, fermentation proceeded very rapidly; in order to watch the results under slower conditions, experiments were made with fermentation at a low temperature, 7° C. (44.6° F.), and were continued for 24 hours. Through A flask hydrogen had been passed, and 4.882 grams of glucose had been fermented; while in B flask, through which air had been passed, the quantity was 5.289 grams. During the 24 hours 190 litres of air had been passed through B flask. In none of the preceding experiments was there any multiplication of yeast.

These results are in striking contradiction to the views of Pasteur, who affirms that in the presence of excess of oxygen fermentation practically ceases. **Brown, on the contrary, finds uniformly that in the presence of oxygen fermentation is more vigorous than in its absence.**

As Pasteur's results were obtained by weighing yeast, Brown in one experiment weighed as well as counted his yeast. At the commencement there were in each flask 87.6 cells per standard volume, and in 100 c.c. 1.903 grams of filtered, washed, and dried yeast. Fermentation resulted in the destruction of 6.20 grams of glucose in the hydrogen flask, and 7.38 grams in the air flask. No increase in the number of cells had occurred, but the weights of yeast, treated as before, were respectively from hydrogen flask 2.130 grams, and air flask 2.060 grams. In both cases there is a slight increase in weight, due probably to assimilation by each individual cell, but in both cases at the finish of the fermentation we have almost exactly *the same weight of yeast,* as well as the same number of cells. Hence equal amounts of yeast, whether determined by weighing or counting, ferment rather more sugar when supplied with air than when deprived of it.

Another important experiment proceeded on different lines. The object was to determine the rate of multiplication of cells, and, at the same time, the rapidity of fermentation. Six similar flasks of glucose in yeast water were taken, and each seeded with 0.65 yeast cells per standard volume. All were allowed to ferment under similar conditions. At intervals, one of the flasks was taken and the number of yeast cells found, and the quantity of alcohol produced determined, with the following results:—

	A.	B.	C.	D.	E.	F.
Time of Commencement of Experiment, and subsequent Determinations in Separate Flasks.	Number of Cells found in each Experiment.	Mean number of Cells present during each interval of Time.	Total grams of Alcohol found in each Experiment in 100 c.c. of the Liquid.	Grams of Alcohol found in each interval of Time in 100 c.c. of the Liquid.	Proportion of grams of Alcohol per 100 c.c. to a Single Cell in each interval of Time.	Interval of time in each Experiment in Hours.
Jan. 9, 11 p.m.	0.65	—	—	—	—	—
„ 10, 11 a.m.	4.87	2.76	0.654	0.654	0.237	12
„ 10, 11 p.m.	12.03	8.45	1.933	1.279	0.151	12
„ 11, 11 a.m.	15.38	13.70	2.975	1.042	0.076	12
„ 12, 11 a.m.	15.88	15.63	4.237	1.262	0.080	24
„ 13, 11 a.m.	15.80	15.80	6.187	1.950	0.123	24

It will be noticed that the number of cells increases rapidly in the earlier stages of fermentation, and that also the proportion of alcohol produced by each single cell is greatest during the first twelve hours. This is contrary to general views that fermentation is slower during the more rapid multiplication stage of the development of yeast, an effect which was supposed to be a result of oxygen in the liquid, which, while aiding the reproduction of the cells, at the same time limited their fermentative power. Brown's experiments contradict this theory.

In a further paper communicated to the Chemical Society in 1894, A. J. Brown devotes himself to a critical examination of Pasteur's theory; of which criticism the following is a brief outline:—Pasteur, as previously explained, compared the fermentative power of yeast cells under varying conditions of aeration, and arrived at the conclusion that when aeration is perfect, fermentative power ceases, and when aeration is reduced, fermentative power increases. The type of experiment used for this purpose was that of determining, under varying conditions of aeration, the proportion of the weight of the yeast formed to the weight of sugar fermented. This ratio of yeast to sugar is, Pasteur considers, an expression of fermentative power. If, as Pasteur argued, the amount of yeast formed during fermentation were in direct proportion to the sugar fermented, the ratio of yeast to sugar would remain constant, however much or little sugar were available. Brown contends that his experiments show conclusively that such is not the case, there being no direct proportion between weight of yeast formed and sugar fermented. In order to show that the total fermentative power of yeast has not been measured in Pasteur's experiments, a fermentation was carried on under aerobic conditions, until the sugar originally present was decomposed. Afterwards, using the principle of overcrowding as a means of preventing reproduction, the crowded cells were fed with more sugar. Feeding was carried on at intervals until three times the original weight of sugar had been thus fermented, but no increase in the weight of yeast had occurred. In Brown's opinion, Pasteur's apparent deficiency in fermentative power was due to the employment of a limited amount of sugar in the experiment. Brown objects to Pasteur's aerobic experiments in shallow dishes, because they were allowed to continue but a limited time, and therefore a *time* factor is introduced: further, cane-sugar was used as the fermentable material, and consequently the results were complicated by the hydrolytic functions of the yeast having to precede fermentation. Pasteur's measure of fermentative power in the experiments referred to is an expression of the action of the inversion and fermentative functions in a limited *time.* Brown concludes by submitting, in place of Pasteur's theory that fermentation is "life without air," the hypothesis that "**yeast cells can use oxygen in the manner of ordinary aerobic fungi, and probably require it for the full completion of their life-history; but the exhibition of their fermentative functions is independent of their environment with regard to free oxygen.**" Nothing in the results of any of Pasteur's experiments are contradictory to such a hypothesis.

311. Buchner's Views on the Action of Oxygen.—Mention has already been made of Buchner's researches on zymase as the agent through which yeast effects alcoholic fermentation. That investigator, together with Rapp, pointed out in 1898 that Pasteur's views of fermentation were biologically correct, inasmuch as yeast has obtained the power of acquiring its oxygen by means of fermentation instead of by the more usual course of the direct assimilation of oxygen. They show further that oxygen stimulates the multiplication of yeast cells. So thoroughly, however, has yeast acquired the fermentation habit, that even in the presence of oxygen, yeast is far more active as a fermentative agent, than as a mere respiratory organism.

312. Mal-Nutrition of Yeast.—When yeast is deprived of a normal proportion of each of the necessary constituents for its healthy life, the vitality of the cells is thereby lessened. One result of this is that the cells tend to assume abnormal forms. Thus, in the case of prolonged growth, without access of free oxygen, yeast cells elongate, and at times are observed to be several times as long as broad (sausage-shaped). The same peculiarity of outline may be noticed in yeast that has been grown in sweetened water. The reason may be that, with a deficient supply of nutriment, each cell stretches itself out, as it were, in order to expose as great a surface as possible to the medium. It is well known that the area of surface of a sphere is less in proportion to its cubical contents than is that of a cylinder or of any other solid body. By offering a greater surface to the liquid in which it is growing, the yeast cell presumably is enabled to absorb a greater amount of nutriment. In breweries where sugar is largely used as a substitute for malt the yeast suffers from the low percentage of nitrogenous matters contained in the wort: the result is that such yeast has little vitality and is soon exhausted.

Large quantities of mineral salts also affect the shape of the yeast cell; thus, the yeast of Burton ale is oval (egg-shaped) in outline: the Burton water is extremely hard, containing calcium sulphate in large quantities.

Badly nourished yeast, on examination, is usually found to have abnormally thin and fragile cell walls, these being broken by the slightest pressure; the contents of the cells are also thin and watery, instead of full of healthy granulations of gelatinous protoplasm.

313. Sporular Reproduction of Yeast.—In addition to the budding process already described, yeast also reproduces, when deprived of all nourishment, by the formation of spores within the cell. To observe this effect, prepare first a block of plaster of Paris by taking some of the powder, rapidly making it into a thin paste, and then pouring same into a cardboard mould. Let it set, and then strip away the cardboard. Smear on the smooth surface of the plaster a little pressed yeast which has been previously washed in distilled water. Place the block with yeast face upwards in a shallow dish, and pour in water until its surface is just a little below that of the yeast. Cover it over with a glass shade to keep out dust, etc., and stand in a warm place (about 20-25° C.). Each day remove a little and examine under the microscope; after a few days some of the cells will show denser masses of protoplasm aggregated around from two to four points. These gradually grow, and at last occupy the whole of the interior of the cell. They become coated with cell envelopes, and then constitute ascospores. The walls of the ascus or mother-cell after a time disappear, and the liberated spores perform the functions of yeast, inducing fermentation, and reproducing by the ordinary mode of budding. Among the conditions necessary for spore formation are young and vigorous cells, comparative absence of nutriment, and a fairly warm temperature. The speed of spore formation is greatly influenced by the latter condition; within certain limits increase of temperature quickens the formation of spores. This is also termed multiplication by *endogenous* division. Cells containing ascospores are shown in Fig. 11, which represents the first stages of development of the spores of *S. Cerevisiæ* I., after Hansen: *a, b, c, d, e* contain rudiments of spores, with the walls not yet distinct; *f, g, h, i, j* are completely developed spores with distinct walls.

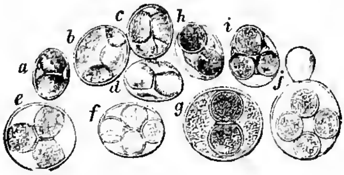


FIG. 11.—Ascospores.

314. Substances inimical to Alcoholic Fermentation.—Dumas has carefully investigated the action of foreign substances on alcoholic fermentation; Schützenberger quotes largely from his results; the following data obtained by Dumas are taken from the English translation of Schützenberger's work. In the first place, a series may be given of those bodies which retard, and when in sufficient quantity absolutely arrest, fermentation. These include the mineral acids and alkalies (phosphoric acid excepted), soluble silver, iron, copper, and lead salts; free chlorine, bromine and iodine, alkaline sulphites, and bisulphites of the alkaline earths, manganese peroxide; essences of mustard, lemon, and turpentine; tannin, carbolic acid (phenol), creosote, salicylic acid; sugar in excess, alcohol when its strength is over 20 per cent.; and hydrocyanic and oxalic acids, even in small quantities. Phosphoric and arsenious acids are inactive. Sulphur has no effect on fermentation, but the carbon dioxide gas evolved contains from one to two per cent. of sulphuretted hydrogen.

As may be gathered from the statement of the chemical changes produced by yeast, that substance gives always a more or less acid reaction. Dumas states that this acidity requires, for its neutralisation, alkali, equivalent to 0.003 grams of normal sulphuric acid per gram of yeast. In his experiments he added various acids to yeast in proportions of from one to a hundred times the normal acid of the yeast. In this manner was determined the retarding or other action of the various acids on fermentation. Similar experiments were made with bases, and also salts; with the latter, saturated solutions were first made; the yeast was allowed to soak in these for three days, and then its fermenting power tested by its action on pure sugar. Dumas divided the salts into four groups. First, those under whose influence the fermentation of the sugar is entire, and more or less rapid; second, those which permit partial but more or less retarded fermentation; third, those which permit the sugar to be more or less changed, but without fermentation; fourth, those that prevent both change and fermentation. Alum is placed in the first of these classes, borax in the second, and sodium chloride (salt) in the third. Strychnine has no effect on the properties of yeast. For a detailed account of Dumas' results the student is referred to Schützenberger's work.

315. Isolation of Yeast and other Organisms.—As a preliminary to the study of varieties of yeast, it is absolutely necessary to have some means of separating and growing each variety in a state of absolute purity. Pasteur did an enormous amount of work in this direction; but the crucial point in all such investigations as these is the purity or otherwise of the yeast used to commence the experiment; in all Pasteur's researches he used an apparatus which afforded most excellent means for the prevention of the incursion of foreign germs during his growth; but he does not give us an absolutely certain method of obtaining a perfectly pure yeast to start with. In flasks of special construction, well known as "Pasteur's Flasks" (Fig. 12), Pasteur introduces wort, then sterilises the same by boiling it, and afterwards sows therein a small quantity of the yeast he wishes to cultivate in the pure state. The Pasteur's Flasks have a long narrow neck, which, as shown in the illustration, is bent twice on itself, the end being stopped with a plug of cotton wool. In addition, there is a side tubulure, stopped with india rubber tubing and a glass plug. The wort is introduced through the side tube, and when boiled the steam escapes through the bent tube. On cooling, the air which enters is sterilised by filtration through the cotton wool. The yeast is sown during a momentary removal of the glass plug. On the completion of this fermentation, a little of the new growth of yeast is taken and transferred with all due precautions to a second Pasteur's Flask of sterilised wort, and there again fermented. The yeast was grown in this way again and again, until the experimenter was of opinion that the preponderating growth of the yeast would have crowded out of existence any foreign germs. To further aid in accomplishing this object, Pasteur also introduced in his growth-flasks some substances inimical to the organisms he wished to exclude, or else worked at a temperature specially favourable to the particular organism whose growth he desired to favour. The yeast obtained in this manner he terms pure yeast; undoubtedly this may be possible, and in many experiments was probably the case; but it is nevertheless only a possibility we have to deal with, for the germs of foreign organisms may not be really dead, but only present in smaller quantity and in a weaker condition. More recent investigators have described methods by which it is possible to cultivate and develop the growth of yeast from one single isolated cell; in this manner giving the surest guarantee of the actual purity of the yeast produced.

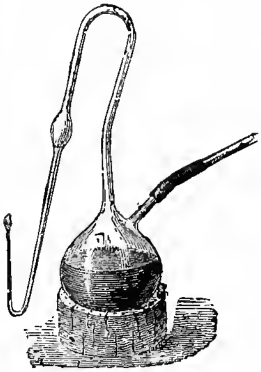


FIG. 12.—"Pasteur's Flask."

A first step in this direction is the adoption of what is known as "Nægeli's Dilution Method," which is based on diluting down the liquid under examination until a single drop will, on the average, contain but one organism. This may be accomplished in the case of yeast by taking a drop of the mixture of yeast and water, diluting it down considerably with water previously sterilised by boiling, until the number of cells present in a drop can be counted under the microscope. If these are estimated, for instance, to be about one hundred, then this liquid is further diluted to a hundred times its volume. Every precaution must be taken to sterilise all vessels and liquids used in the operation. Each drop of this ultimate dilution of yeast should contain one cell only. Ten drops are then placed in 20 c.c. of sterilised water, and thoroughly agitated. One c.c. is then placed in each of 20 separate flasks containing culture fluid, which may, for example, be sterilised wort. The probability is that ten out of the twenty flasks will contain but one organism only, the others remaining unimpregnated. But here again it is only a balance of probabilities, and no certain inferences may be drawn. Hansen proceeded a step further by showing that, if the inoculated flasks are vigorously shaken, and then allowed to stand, the yeast cells will sink to the bottom and attach themselves to the sides of the flask. If more than one cell be present, the probabilities are that they will lie on the bottom some distance apart. After some days the flask is raised carefully, and each yeast cell will be the centre of a small white speck visible to the naked eye, and consisting of a colony of yeast. **In only one such speck be found, the flask contains a pure culture from one cell only.** Subsequent cultivation may proceed on the lines laid down by Pasteur.

Koch, in his experiments on *Bacteria* (certain minute organisms to be hereafter described), used specially prepared gelatin as a cultivating medium. The material was mixed with water until it acquired such a consistency as to set, when cold, into a jelly, which became fluid at a temperature of 35° C. For a cultivation experiment some of the gelatin is melted, a few of the *bacteria* are taken out on the point of a needle and added to the gelatin. They are then diffused by shaking up the mixture, which is next poured out upon a flat surface properly protected. After some hours, a separate and pure culture is obtained from each single *bacterium* present. On taking a minute particle from one of these little culture spots, and again sowing it in gelatin, a single species of *bacterium* was obtained. It was by experiments based on this principle, but carried out with most special precautions, that Koch isolated and exhaustively studied the *"Comma Bacillus"* of cholera, so inseparably associated with his name.

Hansen modified this method for yeast culture, using, instead of Koch's nutrient gelatin (which consisted usually of meat broth and gelatin), a mixture of hopped wort and gelatin. In a bright hopped wort of about 1058 gravity is dissolved from 5-10 per cent. of gelatin, the quantity being regulated so as to cause the mixture to "set" at 30-35° C., being solid below, and liquid above those temperatures. This mixture must, of course, be thoroughly sterilised. Some of the yeast which it is desired to cultivate is first diluted down by the Nægeli method until of a convenient degree of dilution. This must be ascertained by experiment: a drop of this solution is next taken by means of a sterilised piece of platinum wire, and transferred, wire and all, to a flask containing some of the treated gelatin preparation. This is agitated, so as to secure thorough mixture, but at the same time the production of froth must be avoided. A drop of this gelatin is taken out and examined microscopically to determine whether a sufficient number of yeast cells are present. Should they be too crowded, the contents of the flask are diluted with more gelatin; if too few are present, some more must be taken from the yeast-containing flask by means of another piece of platinum wire. To cultivate the yeast, a modification of Koch's glass-plate known as Böttcher's moist chamber, is employed.

The chamber consists of a microscope slide, on which is cemented the glass ring, *c*, the upper surface of which is ground flat. In use, a small quantity of the gelatin and yeast, as prepared above, is placed on the under side of the cover-glass. The upper edge of the glass ring is smeared with vaseline, and a few drops of water placed in the bottom of the chamber. The cover-glass and gelatin is placed on the ring and gently pressed down, when the vaseline makes a tight joint between it and the chamber. Each yeast cell embedded in the gelatin can now be subjected to microscopic examination, and any particular one kept under observation. To do this, any of the devices in common use as finders for any particular part of a microscopic object may be employed, but a very convenient one is Klönne and Müller's marker, which consists of an appliance that can be screwed concentrically into the screw of the microscope which carries the objective. The desired cell is brought into the centre of the field: the objective is removed and the marker substituted for it. By means of the focussing screw it is lowered gently on to the cover, on which it marks a small ring encircling the cell required to be kept under observation. The cell is allowed to develop until a visible colony is formed. By means of a sterilised piece of platinum wire it is now picked off, and used to seed a prepared culture solution in a Pasteur's or other flask. This operation of transference may be conducted in a dust-free room in the open air, but preferably in a small cupboard kept for the purpose, the walls of which have been moistened with glycerin, so as to maintain the interior as a germ-free space. The apparatus, and the hands of the operator, are introduced through a door just sufficiently large to provide for their admission. Large cultures are made, as before, by successive transferences to larger flasks.

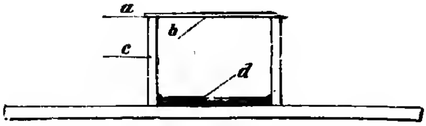


Fig. 13.—Bottcher's Moist Chamber.

a, Thin Cover-glass; *b*, Layer of Nutritive Material; *c*, Glass Ring; *d*, Layer of Sterilised Water.

Hansen's experiments on the effect on brewing, of specific varieties of yeast, were made with cultures obtained in this manner from single cells.

316. Classification of Yeasts.—In classifying yeasts as a genus of the fungi, they have received the following definition, based upon that of Rees.

CLASSIFICATION OF THE GENUS SACCHAROMYCES.

Budding Fungi, mostly without a mycelium, the individual species of which occur with cells of different form and size. Under certain treatment, and sometimes also without any previous treatment, cell-nuclei are seen. Under certain conditions the cells develop *endogenous spores;* the germinating spores of most species grow to budding cells; in exceptional cases a promycelium is first formed. Number of spores 1 to 10, most frequently 1 to 4. Under favourable conditions the cells secrete a gelatinous network, in which they lie embedded.

The greater number of the species induce fermentation.

The following is a list of the more important species:—

Saccharomyces cerevisiae	High Yeast. Low Yeast.
,, *Minor*	Ferment of Leaven.
,, *Ellipsoideus*	Ferment of Wine.
,, *Pastorianus.*	

317. Saccharomyces Cerevisæ, or Ordinary Yeast.—At least two distinct varieties of ordinary yeast are known, to which the names of "High" and "Low" yeast have been given. The former of these is the common yeast of English ale fermentation; the other, that of the well-known "lager" beer of continental production. *Saccharomyces minor,* a species of yeast found in leaven, is also possibly a sub-variety of *S. cerevisiæ;* so, too, is the distillers' yeast made in this country, and also imported from Holland and France, and sold as compressed yeast.

318. High Yeast.—This variety is so-called because of its ascending to the top of the fermenting liquid during fermentation. It consists of cells mostly round or slightly oval, from 8 to 9 μ in diameter, and answering generally to the description of yeast given in paragraphs 301 and 302. Illustrations of Brewers' High Yeast, Distillers' Yeast, and Bakers' Patent Yeast are given in Plate II., to which reference is also made in Chapter XII.

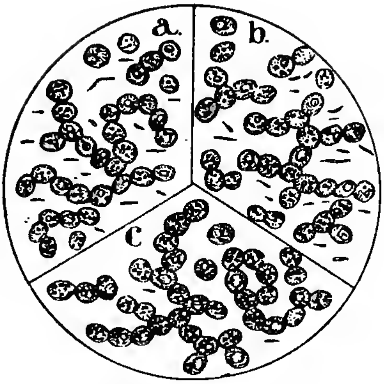
319. Low Yeast.—Sedimentary yeast, or the "low" variety of *Saccharomyces cerevisiae,* is that used in the manufacture of lager beer. In general properties it much resembles the high yeast which has already been studied. In form the cells are somewhat smaller, and also rather more oval than those of normal high yeast; but differ very little in shape from high yeast when grown, as at Burton, in very hard waters. Fig. 9, paragraph 301, gives illustrations of low yeast.

320. Distinctions between High and Low Yeast.—Whereas high yeast rises to the surface of the liquid during fermentation, "low" yeast always falls to the bottom, and forms a sediment there; hence the name "sedimentary" yeast. Brewing with low yeast is performed at much lower temperatures than with high; thus, whereas with the latter pitching temperatures of 20° or 21° C. (68° or 70° F.) are employed, the lager beer brewer starts his fermentation at as low as 8° C. (47° F.), or even 6° C. (43° F.). Working with this low temperature, fermentation proceeds much less rapidly than with high yeast; growth and reproduction proceed more slowly, and the budding gives rise to less extensive colonies of cells. As Pasteur aptly describes it, low yeast when growing has a much less ramified appearance. (See Fig. 10.) It is doubtful whether the term "low," as applied to this yeast, has been given from the lowness of the temperature employed for fermentation, or because the yeast always drops to the bottom of the fermenting vat; both are characteristics of this variety. This yeast is further distinguished by its producing a different type of beer to the celebrated product by high fermentation of English and Scotch breweries.

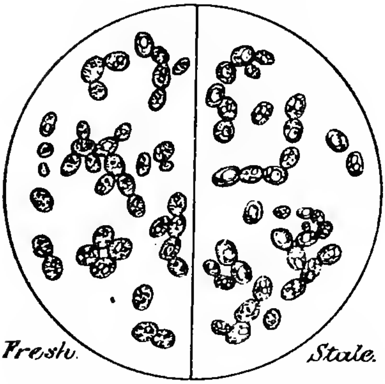
It may be well to mention that the low yeast of lager beer is *not* that which is being imported from the continent, and sold so largely for bread-making purposes. As a matter of fact, lager beer yeast is very badly suited for the fermentation of bread; its action is extremely slow, and results in the production of a heavy, sodden, and frequently sour, loaf.

321. Convertibility of High and Low Yeasts.—This has been for many years a much-discussed problem both by brewers and scientists, and is typical of the discussions which arise on the general question of the immutability or otherwise of the different yeast species and varieties. Students who approach this subject with a previous knowledge of the laws of the origin of species as a result of evolution, as enunciated and demonstrated by Darwin, will be prepared to expect from the general evidence of biology that not only high and low yeasts, but also all forms and species of *saccharomyces,* have had one common origin, their diversities

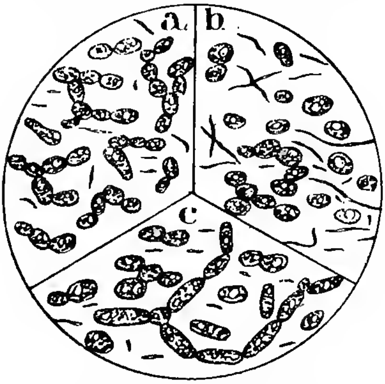
PLATE II.



Brewers' Yeast.



Compressed Distillers' Yeast.



Bakers' "Patent" Yeast.

VARIOUS COMMERCIAL YEASTS.

Saccharomyces Cerevisiæ.

Magnified about 400 Diameters.

A.E. Fuller.

having been produced by differences in environment extending over numberless generations. When discussing, however, whether or not low and high yeast are convertible, and really therefore of the same species, it is understood that the question refers to convertibility during small amounts of time, not such lengthy periods as are requisite for an actual evolution of distinct species. Pasteur, at an earlier period of his researches, considered the two yeasts to be convertible, but as the result of later investigations, affirmed the two yeasts to be distinct. This belief is founded on experiments in which high yeast is grown repeatedly at the lowest possible temperature, and low yeast at the temperature employed for high fermentation. Supposing the yeasts to be pure at the commencement of such an experiment, he asserts that no transformation of the one variety into the other is effected. In this opinion he differs from many brewers, who state that under such conditions the one yeast is converted into the other. Pasteur gives the following explanation of the observed change: if the high yeast had in it a few cells of low yeast as impurity, on being sown and caused to reproduce at a low temperature, the low yeast cells present would thrive well, while the high yeast would languish. The minute quantity of low yeast cells, finding the conditions favourable to their growth, develop; and the others, through the conditions being unfavourable, are after a time outnumbered and disappear. The change of low into high yeast is explained as being just the converse of that now described. An authoritative dictum on this subject is that of Jörgensen, who, in 1893, asserts that, "in spite of many assertions to the contrary, it has not hitherto been possible to bring about an actual conversion of top-yeast into bottom-yeast, or vice versa. The investigations of Hansen and Kühle show that it is certainly possible for a bottom-fermentation yeast to produce transitory top-fermentation phenomena; these, however, quickly disappear with the progressive development of the yeast."

322. Distillers' Yeast.—The yeasts employed by distillers for the purpose of fermenting their worts differ in some most important characteristics from ordinary brewers' yeast. They are, in the first place, grown in un-hopped worts, as against the hopped worts of the brewer. In appearance they resemble low yeast more closely than the normal brewers' high yeast, averaging slightly smaller in size, and forming less extensive colonies. The yeast is less mucilaginous than that of the brewer, and so does not form so sticky a mass. The distillers' yeasts are ordinarily high yeasts, but see the subsequent account of compressed yeast manufacture, Chapter XII. They are sharply separated from the brewers' yeast by their capacity for inducing a vigorous fermentation in dilute mixtures of flour and water. If equal weights of brewers' and distillers' yeast be sown in a solution of sugar in water, and fermented under the same conditions, the brewers' yeast will usually cause a slightly more rapid evolution of gas; but if, instead, a mixture of flour and water be used, the distillers' yeast will cause many times more gas to be evolved than does that from the brewer. This difference is not owing to the absence of sugar, for if to the flour and water sugar be added in the same proportion as in the pure sugar solution, there is still little or no more fermentation caused by the brewers' yeast. The probable reason is the actual toxic effect of certain constituents of flour on brewers' yeast. (See paragraph 377.)

Jörgensen states that distillery yeasts exhibit marked differences in their sedimentary forms, and in ascospore formation, to brewers' yeasts. Microscopic examination of compressed yeast, according to Belohoubek, indicates, in the following manner, alterations in the appearance of the cells. As decomposition sets in, the protoplasm becomes darker in colour and more liquid; the vacuoles become larger, and the sharp outline between them and the plasma gradually disappears: the plasma shrinks from the cell-wall, and finally collects in irregular masses in the cell-fluid. At times cells appear in pressed yeast, which suddenly develop a number of small vacuoles; these abnormal vacuolar cells speedily perish.

323. Saccharomyces Minor.—This is a form of yeast described by Engel as being obtained by him from leaven (a name given to old dough). To obtain the ferment he washes a piece of leaven in the same way as described in a previous chapter for the separation of the gluten of flour from its starch. The yeast cells pass through, and may be detected by microscopic examination of the liquid after the larger starch cells have settled to the bottom. The cells of *Saccharomyces minor* are globular, occurring either isolated or in pairs or groups of three. They are about 6 mkms. in diameter, and have an indistinct vacuole. In Pasteur's fluid they reproduce but slowly, and form new cells of the same dimensions as were the original. They easily reproduce by sporulation, the spores being about 3 mkms. in diameter, and are united in twos or threes. They, on the whole, closely resemble the yeast of beer. Although Engel treats saccharomyces minor as a distinct variety, the balance of evidence is in favour of its identity with *S. cerevisiae.* Grove considers it to be but a form of that ferment. The lesser size and activity may be attributed to its having continually reproduced itself in an unfavourable medium, such as dough; hence its stunted appearance and slow growth, as compared with the more favourably environed yeast of beer.

Engel views this form of yeast as being the active ferment in the fermentation of bread. In this, of course, he is referring to continental black bread, in the fermentation of which leaven is employed, this being made by kneading together flour, bran, and water, and allowing the mass to undergo spontaneous fermentation.

White bread fermented with either brewers' or distillers' yeast belongs to a totally different category.

Saccharomyces minor and other yeast varieties are illustrated in Plate III. The numbers following the multiplying sign give the magnification in diameters.

324. Saccharomyces Ellipsoideus.—This is the ordinary ferment of vinous fermentation, that is, that by which "must," or the expressed juice of the grape, is converted into wine. The cells of this variety of yeast are oval, and about 6 mkms. long; they reproduce both by budding and spores. When grown in malt wort, they produce a beer of a decided vinous flavour, which is sometimes made and sold as "barley wine."

325. Saccharomyces Pastorianus.—The cells of this variety of yeast vary considerably in size; they are cylindrical in shape, with oval ends, and appear when seen in colonies somewhat like strings of sausages. Budding occurs at the joints, where groups of smaller

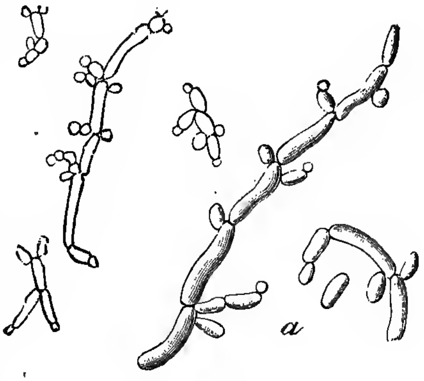


FIG. 14.—Saccharomyces Pastorianus.

a, The same more highly magnified (after Pasteur).

daughter cells may be observed; these are first either round or slightly oval. The elongated cells are from 18 to 22 mkms. long, and about 4 mkms. in diameter; the daughter cells are about 5 to 6 mkms. in length.

S. Pastorianus occurs in the after fermentation of wine and beer, and also in bakers' "patent" yeasts. As it is found in English beers which have been kept for some time in store, cells of it are probably more or less present in all commercial English yeasts. Being a less active variety than *S. cerevisiae,* it remains dormant while the first or principal fermentation proceeds; but when the most of the sugar has disappeared, the *S. pastorianus,* being able to live and develop in a less nutritious medium, grows and reproduces. Brown and Morris point out that the amyloïns cannot be either fermented or hydrolysed by ordinary yeast; but that *S. pastorianus* is capable of hydrolysing maltodextrin for itself, thus giving rise to an apparent direct fermentation of that body. This will explain how this latter ferment thrives and reproduces in a medium so deficient of sugar as not to permit the growth of *Saccharomyces cerevisiæ.*

326. Saccharomyces Mycoderma, or Mycoderma Vini.—Closely allied to the *saccharomyces* already described under the name of yeast is this species, which belongs to the fungus family proper. *Saccharomyces mycoderma* requires for its growth and development free oxygen, and belongs to Pasteur's division of "aerobian" plants. Although the fungi proper luxuriate rapidly when growing with free access to air, yet they are speedily destroyed by enforced submergence below the surface of a liquid. *Saccharomyces mycoderma* occurs on the surface of wine, beer, and bakers' yeasts, on their being exposed for some days to the air, forming after a time a thick wrinkled skin or mycelium; in which state it is said to be "mothery." The mycoderma is known as that of wine (vini), or of beer (cerevisiæ) according to the liquid on which it appears. Viewed under the microscope, the mycelium is found to consist of extending branches of elongated cells closely felted or intertwined together. See illustration on Plate III., and Fig. 15 of *Mycoderma cerevisiæ.* The individual cells are either oval or cylindrical, with rounded ends. They are about 6-7 mkms. long, and 2-3 mkms. in diameter. The *Mycoderma vini* reproduces either by budding or by spores. The spore forming cells attain a length of as much as 20 mkms. Particularly in summer time, the growth of this fungus proceeds with extreme celerity, the mycelium first formed being thrown into folds by its rapid development; at the same time considerable heat is produced. Microscopic examination shows that *Mycoderma vini* is very like yeast in appearance; for a long time it was supposed that the two were identical. and that the mouldiness of beer was produced by the yeast cells ascending to the surface. and there developing as a fungoid growth. The two organisms are, however, distinct species, and have not been transformed one into the other. *Mycoderma vini* during its growth seizes oxygen with great avidity, entirely preventing, during the period of its actual life, the development of other organisms also requiring oxygen, but endowed with less vital energy. Pasteur states that on submerging this mould

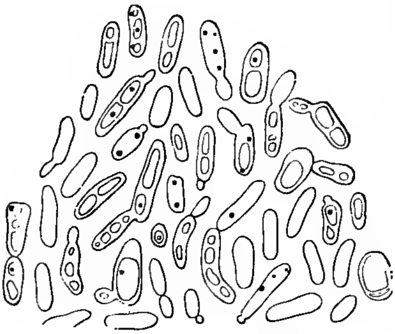
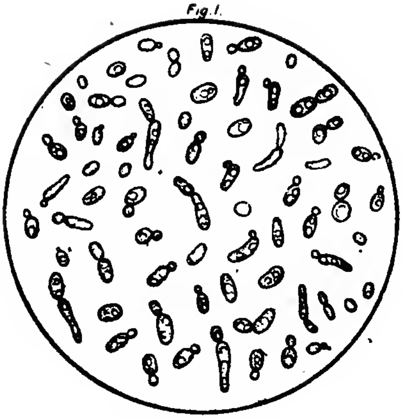


FIG. 15.—Mycoderma cerevisiœ. From Copenhagen Breweries.

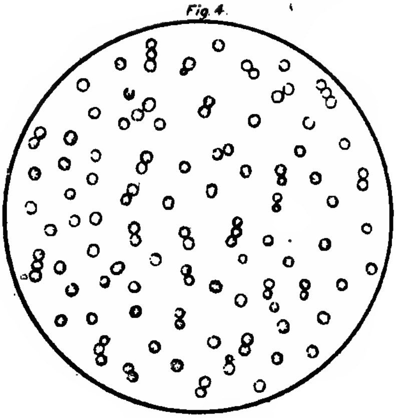
PLATE III.

Fig. 1.



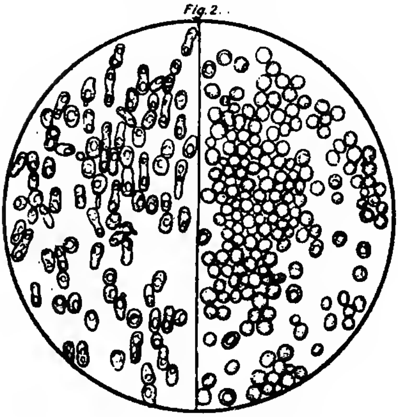
S. Pastorianus. x 360.

Fig. 4.



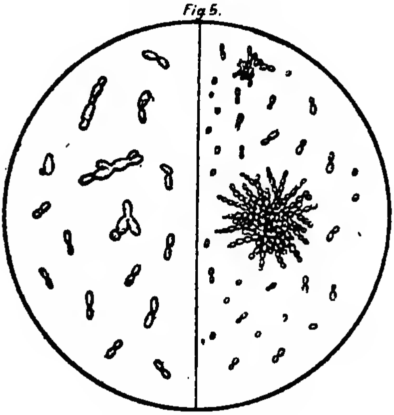
S. Minor x 350.

Fig. 2.



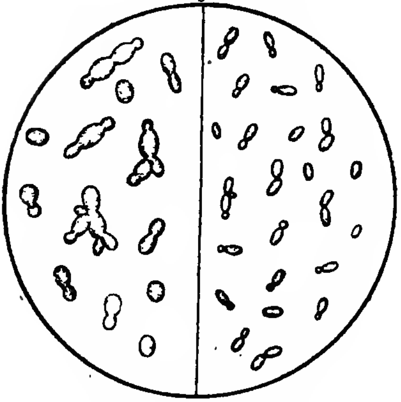
Caseous Yeasts. x 360
L.H N° 1 R.H. N° 2.

Fig. 5.



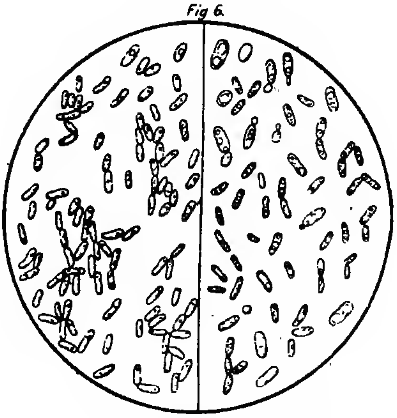
S. Exiguus. x 300.
L.H After Reess. R.H. M.&L.

Fig. 3.



S Ellipsoideus. x 300.
L.H After Reess R.H. M.& L.

Fig 6.



Mycoderma Vini x 300
L.H. Aerobian form. R.H. Submerged form.

(after Matthews & Lott)

VARIOUS "FOREIGN" YEASTS.

during its actual growth into malt wort, or other saccharine liquid, it for a short time causes fermentation, with the production of small quantities of alcohol; but this action soon ceases with the early death of the fungus. In addition to this limited fermentative action, *Mycoderma vini* acts on wines and beers as a somewhat powerful oxidising agent; it conveys the oxygen of the air to the alcohol of the liquid, causing its complete slow combustion into carbon dioxide and water, and consequently rapidly lessening the alcoholic strength of the medium. Although wines and beers become sour simultaneously with the development of *Mycoderma vini,* the souring is not due to this organism, but to another distinct growth.

The limited alcoholic fermentation produced by *Mycoderma vini* leads to its being classed among the *saccharomyces.*

327. Hansen on Analysis of Yeasts.—It is principally due to the researches of Hansen that we are able to classify yeasts into species and races with such accuracy as is now possible. The results of his work have had such important effects on the brewing industry, and indirectly on that of bread-making, that the present book would not be complete without some reference to these classical investigations.

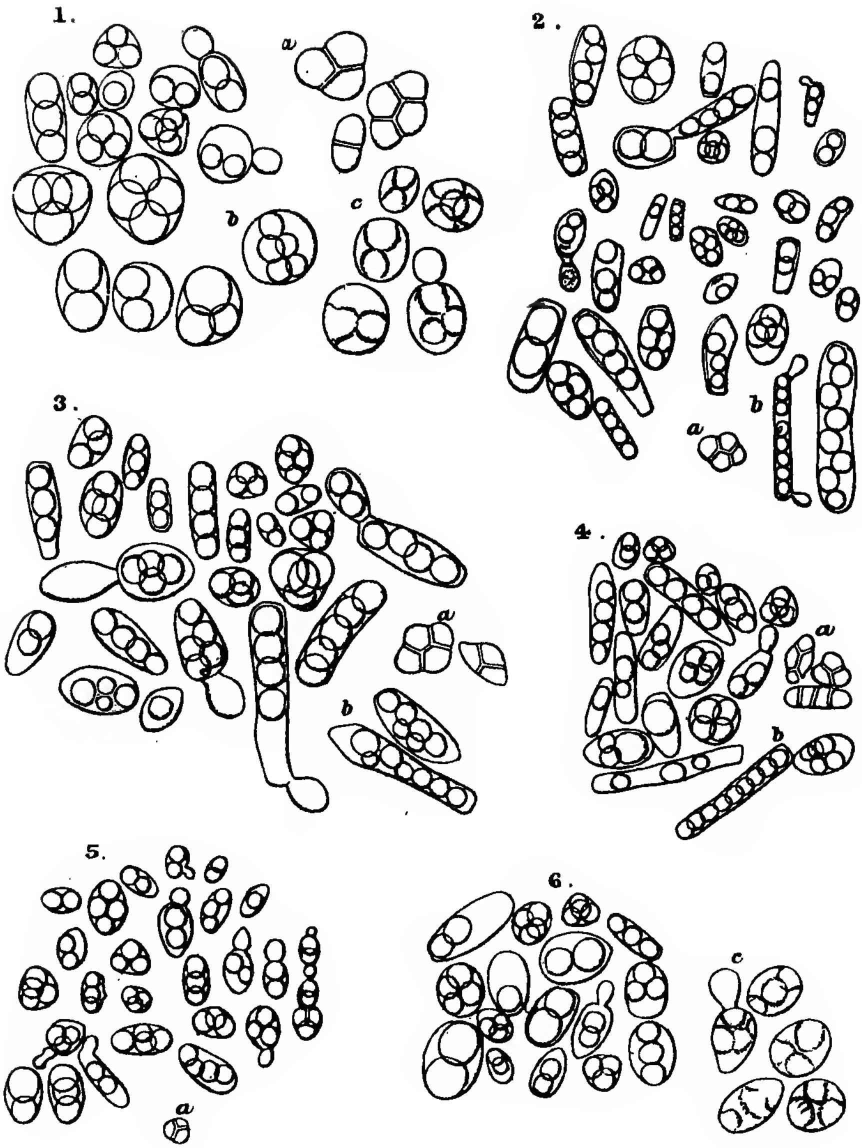
Hansen's fundamental idea was that the shape, relative size, and appearance of yeast cells, taken by themselves, were not sufficient to characterise a species, since the same species under different external conditions could assume very different forms. Further, although, for example, a microscopic field of pure *S. cerevisiae* could be distinguished by its appearance from pure *S. pastorianus,* yet in a mixture of the two it is not possible to distinguish individual cells of the one from those of the other. *S. cerevisiae* forms at times sausage-shaped cells, while *S. pastorianus* occurs to a certain extent as round or oval cells. Some other method, then, than microscopic examination is necessary for their differentiation.

328. Formation of Ascospores.—By investigation of the conditions under which different races of yeast formed ascospores, Hansen was enabled to arrive at a mode of analysis of yeasts. A description of the mode of procedure by which ascospores are obtained has already been given, but Hansen ascertained with more exactitude the precise conditions necessary, and thus sums up his conclusions:—The cells must be kept moist and have a plentiful supply of air; further, to form spores they must be young and vigorous. For most species a temperature of 25° C. is the *most* favourable; for all species this temperature favours their development.

Hansen found the process of spore-formation to vary in different species. *S. S. cerevisiae, pastorianus,* and *ellipsoideus* germinate into spores in essentially the same way. *S. ludwigii* and *S. anomalus* have each a separate and distinct mode of spore growth.

While all species form spores at 25°, Hansen set himself to determine whether with different species there was any difference in their behaviour under varying conditions of temperature. In making observations, he registered the time when the cells first showed distinct indications of spore formation. The limits of temperature for all species are between from 0.5 to 3°C. and 37.5°C. At the highest temperature all species develop first indications in about 30 hours, and show very little difference in time at 25°C.; but with lower temperatures very evident differences occurred. Hansen also found that there were differences in anatomical structure of spores that could be utilised for analytic purposes. In the so-called cultivated yeasts, *S. cerevisiæ* employed for brewing, the spores

PLATE IV.



Formation of Ascospores

1. *Sacch cerevisiæ I.*
2. *Sacch. Pastorianus I.*
3. *Sacch Pastorianus II.*
4. *Sacch. Pastorianus III.*
5. *Sacch. ellipsoideus I*
6. *Sacch. ellipsoideus II.*

(after Hansen × 1000.)

have a distinct membrane, with non-homogeneous granular contents and a definite vacuole. In the case of the so-called wild yeasts, the spore wall is frequently indistinct, the cell contents homogeneous, and the vacuole absent.

Hansen investigated very closely the following six species of yeast, particulars of which are furnished.

Illustrations of the formation of ascospores are given in Plate IV.

Saccharomyces cerevisiae I., English top-fermentation yeast. Ferments glucose and maltose very vigorously. Spores strongly refractive to light, walls very distinct; size 2.5-6 μ.

S. pastorianus I., Bottom-fermentation yeasts; frequently occurs in the air of fermenting rooms; imparts to beer a disagreeable bitter taste and unpleasant odour; can also produce turbidity and interfere with clarification in fermenting vat. Size of spores, 1.5-5 μ.

S. pastorianus II., Feeble top-fermentation yeast; found in air of breweries; apparently does not cause diseases in beer. Size of spores, 2-5 μ.

S. pastorianus III., Top-fermentation yeast, one of the species which produce *yeast-turbidity* in beer; but in certain cases clarify opalescent worts. Size of spores, 2-5 μ.

S. ellipsoideus I., Bottom-fermentation yeast; occurs on *ripe grapes.* Size of spores, 2-4 μ.

S. ellipsoideus II., Usually bottom-fermentation yeast; causes *yeast turbidity,* more dangerous than *S. pastorianus III.*; also imparts a sweetish, *disagreeable, aromatic* taste to beer, and a *bitter, astringent aftertaste.* Size of spores, 2-5 μ.

It will be noticed that Hansen sub-divides both *S. pastorianus* and *ellipsoideus.* He also sub-divides other species into different races or varieties. The leading points of connection between temperature and spore formation are given in the following table:—

TEMPERATURE AND SPORE-FORMATION OF YEASTS.

	Sacch. Cerev. I.	Sacch. Past. I.	Sacch. Past. II.	Sacch. Past.III.	Sacch. Ellip.I.	Sacch. Ellip.II.
Highest limit of development. Temperature of	37.5°	31.5°	29°	29°	32.5°	35°
Most rapid development. Temperature of	30°	27.5°	25°	25°	25°	29°
Most rapid development. Time, in hours, of appearance of first indication of spores	20	24	25	28	21	22
Time, in hours, of appearance of first indications at 15°C.	110	50	48	48	45	62
Lowest limit of development. Temperature of	9°	0.5°	0.5°	4°	4°	4°

It will be seen that considerable differences exist between the various yeasts in the particulars given. In addition, Hansen has also investigated the conditions of film formation and other properties which aid in the task of yeast differentiation.

329. Detection of "Wild" Yeasts.—In utilising spore formation, cultures are made at temperatures of 25° and 15° respectively, the latter being examined after three days—72 hours. All the wild yeasts will have commenced to show indications, while the cultivated yeast will be free from them. When used practically for technical purposes, this method is capable of detecting with certainty an admixture of 0.5 per cent. of a wild yeast in an otherwise pure culture. For this and other tests applied to yeast by Hansen's methods, it is essential that the preliminary trials of the yeast be uniform, so as to make the tests comparative.

330. Varieties of Cultivated Yeast.—Not only have distinctions been drawn between cultivated and wild yeasts by the methods just described, but also well-marked and distinct varieties of cultivated yeast have been grown. Each of these possesses distinct characteristics, and is valued for certain kinds of beer. Thus, Jörgensen, *for practical purposes,* classifies different races of yeast prepared by pure culture methods in his laboratory into the following groups:—

A.—Bottom-Fermentation Species.

1. Species which clarify very quickly and give a feeble fermentation in the fermenting vessel; the beer holds a strong head. The beer, if kept long, is liable to yeast-turbidity. Such yeasts are only suitable for draught-beer.
2. Species which clarify fairly quickly and do not give a vigorous fermentation; the beer holds a strong head; high foam; yeast settles to a firm layer in the fermenting vessel. Beer, not particularly stable as regards yeast-turbidity. Yeasts are suitable for draught-beer, and partly for lager beer.
3. Species which clarify slowly and attenuate more strongly; the beer has a good taste and odour; the yeast deposit is less firm in the fermenting vessel. Beer is very stable against yeast-turbidity. These yeasts are suitable for lager beer, and especially for export beers which are not pasteurised or treated with antiseptics.

B.—Top-Fermentation Species.

1. Species which attenuate slightly and clarify quickly. The beer has a sweet taste.
2. Species which attenuate strongly and clarify quickly. Taste of beer more pronounced.
3. Species which attenuate strongly, clarify slowly, and *give a normal after-fermentation.* The beer is stable against yeast-turbidity.

Hansen has isolated two yeast races from ordinary yeast, both of which are employed in the Carlsberg breweries; these are known as Carlsberg No. I. and Carlsberg No. II. Each has distinct properties of its own; thus, No. I. gives a beer well adapted for bottling, containing less carbon dioxide than No. II., and possessing a lower degree of attenuation; well adapted for home use. No. II. is principally cultivated for export, giving a good draught-beer containing more carbon dioxide.

Passing for the moment the work of different investigators in review, Pasteur freed yeasts from weeds or foreign vegetable growths of the bacteria group. Hansen first eliminated wild yeasts as a fruit grower might eliminate crab-apples and other wild fruits from his orchard. Lastly, he has devoted his attention to the growth of distinct breeds of cultivated yeast, each specialised for a particular type of beer. Jörgensen's experiments carry the analogy a step further. He finds that among the progeny of a single yeast-cell, cells can be selected which may show important differences in respect of the taste, smell, and other properties of the fermented liquid. Such cells may, in fact, differ from each other as do children of the same parents.

In yeast factories much the same is being done for the bakers. Yeasts are selected for their vigour and capacity for fermentation, and these are cultivated to the exclusion of types incapable of yielding such excellent results. Thus Lindner has introduced a variety of pure culture yeast in most of the distilleries of Germany, under the name of Race II. The results have been good. A further development on the same lines is the employment of pure cultures of the bacillus of lactic acid in distilleries. As subsequently described, this serves to inhibit excessive development of lactic acid itself, and butyric acid fermentation. Race V. has been specially recommended for this purpose.

EXPERIMENTAL WORK.

331. Substances produced by Alcoholic Fermentation.—Prepare some ten or twelve ounces of malt wort, by mashing ground malt in five times its weight in water; and take its density by a hydrometer. To the wort add a small quantity of either brewer's or compressed yeast, place it in a flask arranged with a cork and leading tube, and set it in a warm place (30-35° C.). Attach the leading tube to a flask containing lime-water, so that any gas evolved by the yeast has to bubble through the liquid. Notice that after a time fermentation sets in, and that the yeast rises to the top; gas bubbles through the lime-water and turns it milky, thus showing that carbon dioxide is being evolved. When the liquid becomes quiescent through the cessation of fermentation, again take its density with the hydrometer, notice that it is less than before; return the liquid to the flask, and connect to a Liebig's condenser and distil; notice that the first drops of the distillate have the appearance of tears, as described in paragraph 101, Chapter III. Cease distilling when about one-tenth of the liquid has distilled over; notice that the distillate has an alcoholic or spirituous odour. Test it for alcohol by the iodoform reaction.

332. Microscopic Study.—Proceed with this on the lines of paragraph 301.

Mount a trace of the yeast in a little warm malt wort, and examine carefully: notice alteration in appearance of the yeast cells as they set up fermentation: keep the microscope with slide in focus for some time in a warm place, and observe from time to time the changes as they proceed. Watch specially for the development of budding, and as soon as any signs are detected watch the cell at short intervals until the bud has become completely detached from the parent cell.

Sow a little yeast in a beaker in a small quantity of wort; take out a little and examine under the microscope a few hours later: examine again on each successive day until some three or four days have elapsed since the fermentation has ceased. Note during the height of the fermentation the colonies of cells, sketch some of these: observe the clear outlines and transparent protoplasm of the new cells as compared with the shrunken appearance of the parent cells. As time proceeds, notice the gradual alteration in appearance of the yeast, until at last the new cells are similar in appearance to those originally sown.

Study sporular reproduction as directed in paragraph 313.

CHAPTER X.

BACTERIAL AND PUTREFACTIVE FERMENTATIONS.

MOULDS.

333. **Schizomycetes.**—Grove defines the *Schizomycetes* or "splitting fungi" (*Spaltpilze*) as being unicellular plants, which multiply by repeated subdivision, and also frequently reproduce themselves by spores, which are formed endogenously. They live, either isolated or combined in various ways, in fluids and in living or dead organisms, in which they produce decompositions and fermentations, but not alcoholic fermentation.

Among these organisms are included *bacteria, bacilli, vibrios,* etc., but comparatively few of these have an immediate bearing on the present subject, and so the great majority need not here be described.

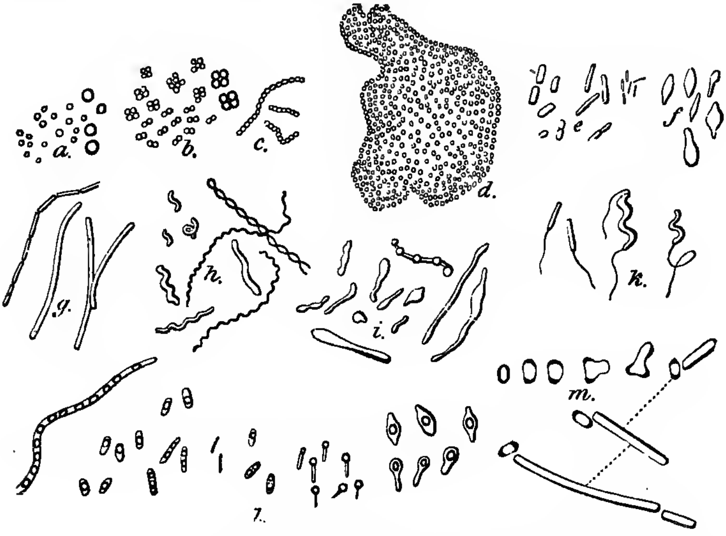


FIG. 16.—Growth-forms of Bacteria.

a, Cocci; *b*, Diplococci and Sarcina; *c*, Streptococci; *d*, Zooglœa; e, Bacteria and Bacilli; *f*, Clostridium; *g*, Pseudo-filament, Leptothrix, Cladothrix; *h*, Vibrio, Spirillum Spirochæte, and Spirulina; *i*, Involution-forms; *k*, Bacilli and Spirilla, with cilia or flagella; *l*, Spore-forming Bacteria; *m*, Germination of the Spore.

The difficulty of classifying the *Schizomycetes* increases with a more minute acquaintance with these organisms, as investigation shows that one and the same organism occurs in varying forms under different conditions. Some of the various growth-forms are illustrated in Fig. 16. If, on the other hand, grouped according to the chemical changes they produce, then in many instances more than one organism is found capable of inducing the same chemical reaction. For the purposes of the present work, it will be more convenient to accept provisionally a classification according to chemical effects produced.

The *Schizomycetes* possess the property of surrounding themselves with a gelatinous substance, in which large colonies of them may be seen imbedded. They are then said to be in the "Zooglœa" stage.

334. Bacteria.—These organisms consist of small cells, commonly cylindrical in shape; they increase by transverse divisions of cells, and reproduce by sporulation. *Bacteria* have a spontaneous power of movement.

ORGANISMS OF PUTREFACTION.

335. Bacterium Termo.—This is essentially the ferment of putrefaction. It is present in air, and also in waters contaminated with sewage. Hay, meat, or flour infusions, malt wort and other liquids, on being exposed to the atmosphere, become turbid, and are then found on microscopic examination to be densely crowded with *bacteria.* The cells are oval in shape and about 1.5 to 2 mkms. in length: they are constricted in the middle, giving them a sort of hour-glass appearance; at each end is an extremely fine filament, termed a "*flagellum,*" and sometimes a "*cilium.*" This is probably the organ by which the *bacterium* exerts its motile or moving power. For illustrations of this and other forms of bacteria see Plate V.

This definite movement of the *bacterium* must not be confounded with the simple oscillatory movement of small particles of matter when suspended in a fluid. This latter may be observed by rubbing up a little gamboge in water, and microscopically examining a drop of the liquid; the small solid particles are seen to be in a continual state of motion. This latter is termed the "Brownian" movement.

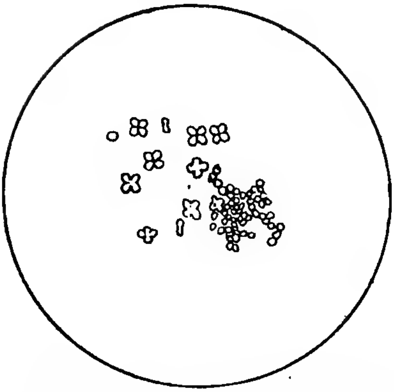
The spores of the *bacteria,* in common with most other of those of the *schizomycetes,* are extremely tenacious of life. They may be dried up and exist in a dormant state for an indefinite time without losing their vitality; for immediately on being again moistened and placed in a suitable medium, they commence an active existence and cause putrefaction. The dry spores are not destroyed by even boiling them for so long as a quarter of an hour; they are also not affected by weak acids.

336. Bacilli.—The word *bacillus* literally means a stick or rod, and is applied to the organisms of this genus because of their rod-like shape. The cells are long and cylindrical and occur attached to each other, thus forming rod-like filaments of considerable length. There is little or no constriction at the joints, which with low microscopic powers are scarcely observable. They increase by splitting transversely, and reproduce by spores. *Bacteria* and *bacilli* are closely allied genera, some species of the one closely resembling species of the other. In the very long cells of *bacteria* the transverse divisions may be detected, while in the equally long cells of *bacilli* no traces of division can be seen. *Bacilli* are sometimes motile, but after a time pass into a condition of rest, or zooglœa stage. The long threads of *bacilli* often assume a zig-zag or bent form; and unless subjected to very careful examination, appear to be continuous. Pasteur's filaments of turned beer "consist of *bacilli.*"

337. Bacillus Subtilis.—This organism is also termed "*Vibrio subtilis,*" and is largely present in air. Owing to its being the predominant organism produced when an aqueous infusion of hay is exposed to the air, it is frequently referred to as the bacillus of hay. The cells are cylindrical, and grow to about 6 mkms. in length, and are provided with a flagellum at either end. They usually occur adherent to each other, forming long filaments, as shown in Plate V.

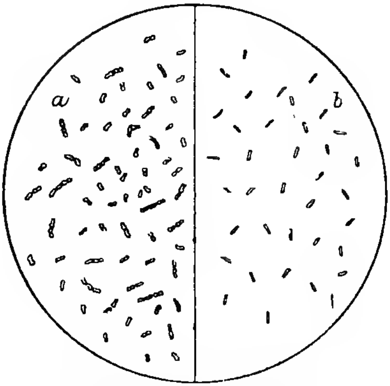
PLATE V.

Fig: 1.



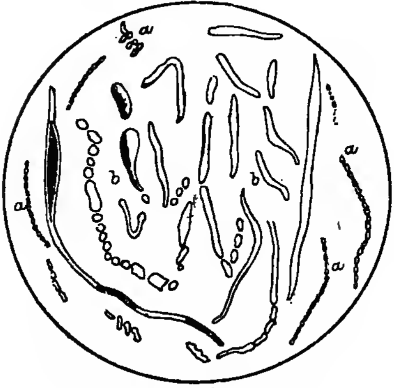
Pediococcus acidi lactici (Lindner) × 1100

Fig: 2



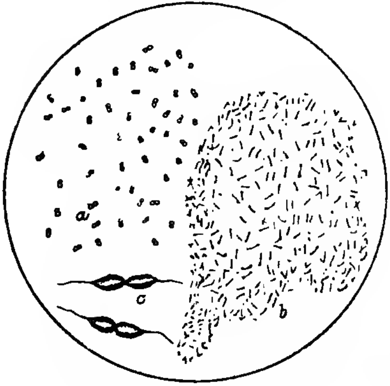
Bacterium lactis × 350
a Pasteur b Matthews & Lott.

Fig. 3



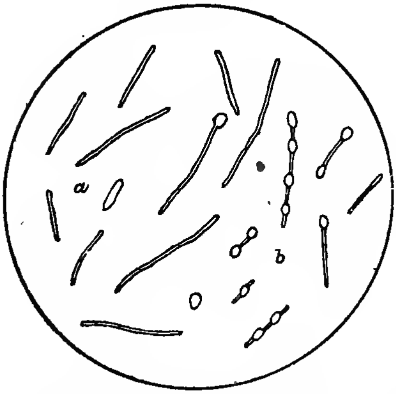
Bacterium aceti. (Hansen) × 400 (about).

Fig: 4



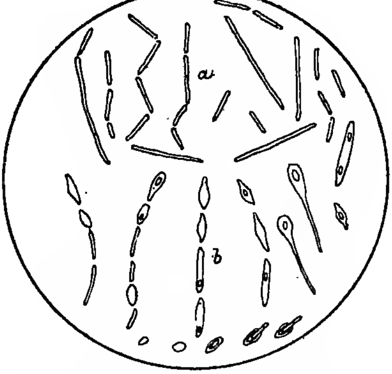
Bacterium Termo. (a & b. Cohn. c, Dallinger) × 650 & × 4000.

Fig: 5



Bacillus subtilis (Cohn) × 650.

Fig: 6.



Clostridium butyricum. (Prazmowski) × 650 (about).

VARIOUS DISEASE FERMENTS.

The term "*vibrio*," applied to certain forms of *schizomycetes*, is derived from their appearing to have a wriggling or undulatory motion; this effect is illusory, being actually caused by their rotating on their long axis.

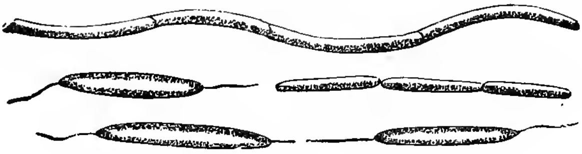


FIG. 17.—*Bacillus subtilis* × 4000 (after Dallinger).

An enlarged illustration of *B. subtilis* is given in the following figure, 17. They increase by transverse division, and reproduce by spores. As the spore formation of *B. subtilis* has been most carefully observed, a description of its mode of reproduction will be of service as a type of that of the *schizomycetes* generally. In spore formation the protoplasmic contents of the cell accumulate at the one end, causing an enlargement there; the rest of the cell after a time drops off and dies; the mature spore may then live for even years without losing its vitality; and being of extreme minuteness, these spores permeate the atmosphere, and are ever ready to germinate on finding a suitable medium. In the act of germination the spore splits its membrane open, and a new rod grows and projects through the opening. The dry spores are extremely tenacious of life, and withstand boiling for an hour in water without losing their vitality. Some three or four consecutive boilings in a flask plugged with cotton-wool, with a few hours' interval between, are necessary to ensure sterilisation from this organism.

Various writers impute different specific fermentative actions to B. subtilis, but it is doubtful whether the production of any particular chemical compound should be associated with it. It is essentially the organism of putrefaction, and effects the decomposition both of nitrogenous and carbonaceous bodies with the evolution of mal-odorous gases. Both it and *B. termo* are stated to possess the power of peptonising proteins, this operation being a preliminary to their further conversion into leucin, tyrosin, and allied bodies.

338. Diastatic Action of Bacteria.—This latter action is a consequence of the property possessed by the *bacteria* of attacking protein bodies and converting them into peptones. Wortmann has devoted considerable attention to the investigation of the problem whether or not *bacteria* have any action on starch: whether or not, by the secretion of a starch-transforming substance similar to diastase, or in any other but not clearly defined way, they are capable of transforming starch into soluble and diffusible compounds. In order if possible to obtain a solution of this problem, Wortmann experimented in the following manner:—

To about 20 or 25 c.c. of water a mixture of inorganic salts (sodium chloride, magnesium sulphate, potassium nitrate, and acid ammonium phosphate, in equal proportions) was added to the extent of 1 per cent. The same quantity of solid wheat-starch was next added, and the liquid then inoculated with one or two drops of a strongly bacterial solution; shaken, corked, and allowed to remain in a room at a temperature of 18° to 22° C. (*Bacterium termo* was the predominating organism in the inoculating fluids employed.) In from five to seven days, the first signs of commencing corrosion of the starch granules had become visible, the larger grains being first attacked, and much later, when these had almost completely disappeared, those of lesser size.

In a second series of experiments, soluble starch was substituted for the solid form, the progress of the reaction being watched by the aid of iodine. Samples taken from time to time exhibited at first the blue colour, then violet or dark red, passing to wine red, and finally, when the starch had disappeared, underwent no change.

Wheat-starch grains are found to be by far the most readily attacked by *bacteria* when compared with other varieties, in several experiments having even completely disappeared before other sorts of starch were affected. Of a number of starches, that of potatoes alone entirely resisted attack. When wheat-starch in the solid state was mixed with starch solution or with starch paste, the solution became entirely (and the paste in greater part) changed before any action occurred on the solid granules.

With regard to this unequal power of resistance shown by different kinds of starch, Wortmann concludes from his further observations that the difference of rapidity with which a given kind is attacked and dissolved by a ferment is inversely proportional to its density, provided always that the granules in question are entire and uninjured by cracks or fissures. In the same way are explained the differences in point of time in which granules of the same kind are sometimes observed to undergo change accordingly as they are intact or otherwise.

The cause of potato-starch, or of bean-starch, and even under certain conditions, wheaten starch, resisting attack, in spite of the abundant pressure of *bacteria,* is apparently to be sought for in the fact that other more easily accessible sources of carbon nutriment were also present, certain protein constituents of the potato slices, or of the beans employed affording this more readily than the starch granules; just as in the experiments above cited, with wheaten starch solution and solid wheaten starch, the former was preferentially attacked; only after all, or at least the chief portion, of the proteins present had been used up, was the starch in these cases attacked.

Another point was also established in the course of these experiments—that if air is excluded, no appearance of corrosion or solution of the starch granules is manifested.

That the starch in the process became changed in part to glucose was easily ascertained by testing with Fehling's solution, and a detailed series of experiments, made with a view to eliminating if possible the ferment itself, yielded evidence showing that *bacteria* possess the remarkable property of producing a starch-transforming ferment, only when no source of carbon other than starch is at their disposal, and this ferment is incapable of changing albumin into peptone, just as in the case of diastase. The results of Wortmann's researches may be briefly recapitulated—

1. *Bacteria* are capable of acting on starch, whether in the solid state, as paste, or in solution, in a manner analogous to diastase.

2. As in the case of diastase, different kinds of starch are attacked by *bacteria* with different degrees of rapidity.

3. The action of *bacteria* on starch is manifested only in the absence of other sources of carbon nutriment, and when access of air is not prevented.

4. The action of *bacteria* on starch is effected by a substance secreted by them, and which, like diastase, is soluble in water, but precipitable by alcohol.

5. This substance acts precisely as diastase in changing starch into a sugar capable of reducing cupric oxide, but is not possessed of peptonising properties.

These results of Wortmann's are quoted at some length because of their bearing on the action of *bacteria* in dough. One most important point is, that the diastatic action of *bacteria,* or their secretions, only occurs in the absence of protein matter, which is the substance most specially suited for the development of these organisms; consequently, with the exception of the transformation of sugar more or less into lactic acid, the carbohydrates are unattacked by the *schizomycetes* during normal dough fermentation. The *bacteria* cause more or less change in proteins, but exert no diastatic action. These protein changes are, by the way, unaccompanied by any appreciable evolution of gas.

It will be noticed that Wortmann expressly states that the *bacteria* have no peptonising action; while it is also as expressly stated that they readily attack the proteins. He does not state what substances he finds produced by this action. The opinion is, nevertheless, very generally held that peptones are produced during changes which occur during the fermentation of dough, and it has been supposed that the *bacteria* were the active agents. Thus, Peters describes a bacillus which he found among the organisms of leaven which possesses a peptonising power.

339. Putrefactive Fermentation.—Putrefaction is that change by which most organic bodies containing nitrogen in a protein form are first resolved into substances having a most putrid odour, and ultimately into inorganic products of oxidation. *Bacterium termo* and *B. subtilis* have already been mentioned as the principal organisms of putrefaction. Pasteur divides the act of putrefaction into two distinct stages, which it will be well here to describe. On exposing a putrescible liquid to the air, there forms on the surface a film composed of *bacteria,* etc.; these completely exclude any oxygen from the liquid, by themselves rapidly absorbing that gas. Beneath, other more active organisms, which Pasteur groups together under the name of "*vibrios,*" act as ferments on the protein matters of the liquid, and decompose them into simpler products; these simpler products are in their turn oxidised still further by the surface *bacteria.* Pacteur practically defines putrefaction, or putrid fermentation, as fermentation without oxygen.

340. Action of Oxygen on Bacterial and Putrefactive Ferments.—Pasteur draws a hard and fast line between certain *bacteria* which he affirms live in oxygen, and absolutely require it, and others to which oxygen acts as a poison; to which latter class he states that the *vibrios* belong. This name is used by him seemingly to refer to those micro-organisms which are in active motion. Of the *bacteria* of the first type, he mentions that if a drop full of these organisms be placed on a glass slide, and examined with a microscope, there is soon a cessation of motion in the centre of the drop, while those *bacteria* nearest the edges of the cover-glass remain in active movement in consequence of the supply of air. On the other hand, if a drop of liquid containing the *vibrios* of putrefactive fermentation be studied in a similar way, motion at once ceases at the edge of the cover-glass; and, gradually, from the circumference to the centre, the penetration of atmospheric oxygen arrests the vitality of the *vibrios.* Pasteur thus divides the *bacteria* into an *aërobian* and an *anaërobian* variety; the former require oxygen, the latter find it a poison, and live and thrive best in its total absence. In proof of this view he describes experiments of a most careful character made by him.

341. Conditions Inimical to Putrefaction.—First and foremost among these is the keeping out of the germs of putrefactive ferments from the substance. Meat and protein bodies, generally, have come to be ordinarily viewed as very changeable substances, whereas in the absence of germ life they are very stable bodies. Putrefaction is the concomitant, not of death but of life. If animal fluids are drawn off into sterilised vessels without access of air, they keep for an indefinite length of time. Or the germs may be destroyed by heat, when putrescible substances also remain unchanged. This latter is the basis of Appert's methods for the preservation of animal substances. These methods consist of exposing the substances to a sufficiently high temperature in hermetically sealed vessels; or they may be heated in vessels so arranged that air may escape, but that any re-entering shall be freed from bacterial germs either by passing through a red-hot tube, or by being filtered through a thick layer of cotton-wool.

Tinned meats, milk, etc., are preserved on this principle of Appert's.

Putrefaction may be arrested by intense cold, although even freezing *bacteria* does not destroy their power of inducing putrefaction when again warmed. As a consequence of this action of cold, meat when thoroughly frozen may be preserved almost indefinitely. The absence of water is another preventative of putrefaction. Vegetables and meat, if thoroughly desiccated, show, on keeping, no signs of putrefying. In the same way, yeast, although in the moist state one of the most putrescible substances known, may, by being carefully dried, be kept for months, not merely without putrefying, but also without destroying the life of the cell.

342. Products of Putrefaction.—These are exceedingly numerous and complex, among them may be found volatile fatty acids, butyric, and others of the series; ammonia, and some of the compound or substitution ammonias; ethylamine, trimethylamine, propylamine, etc.: carbon dioxide, sulphuretted hydrogen, hydrogen, and nitrogen.

LACTIC AND OTHER FERMENTATIONS.

343. Lactic Fermentation.—This is primarily the fermentation by means of which milk becomes sour. The chemical change is a very simple one. Milk contains the variety of sugar known as lactose or sugar of milk, $C_{12}H_{22}O_{11}$. By hydrolysis, this splits up into two molecules of a glucose called lactose, galactose, or lacto-glucose, $C_6H_{12}O_6$. When subjected to the influence of the lactic ferment, lacto-glucose is decomposed according to the following equation:—

$$\underset{\text{Lacto Glucose.}}{C_6H_{12}O_6} = \underset{\text{Lactic Acid.}}{2HC_3H_5O_3}.$$

Ordinary glucose, and also cane-sugar and maltose, are susceptible of the same transformation. From numerous recent researches, there is evidence of a number of organisms which possess the power of producing lactic acid by the conversion of glucose. One or more of these is always found present in greater or less quantity in commercial yeasts, also on the surface of malt; in the latter case it may be detected by washing a few of the grains in water, and then examining the liquid under the microscope. Its shape, according to Lister, when developed in milk, is shown in the accompanying illustration. When viewed with a lower power in a field of yeast, the lactic ferment appears as small elongated cells somewhat constricted in the middle, generally detached, but occurring sometimes in twos and threes; their length is about half that of an ordinary yeast cell. When single they exhibit the Brownian movement.

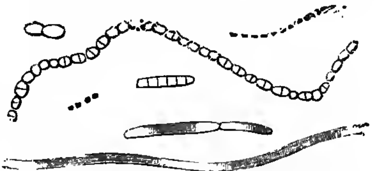


FIG. 18.—*Bacterium lactis* × 1140 (after Lister).

Lactic fermentation proceeds most favourably at a temperature of about 35° C., and is retarded and practically arrested at a temperature which still permits the growth and development of the yeast organism, and consequent alcoholic fermentation. For this reason brewers always take care to ferment their worts at a low temperature, thus preventing the lactic ferment, which is always more or less present, from any rapid development. The other bacterial and allied ferments are also affected in a similar manner by temperature. Dilute solutions of carbolic and salicylic acids (and also hydrofluoric acid) greatly retard lactic fermentation, while in such very weak solutions they have but little action on the yeast organism; hence yeast is sometimes purified by being repeatedly grown in worts, to which small quantities of these acids have been added. The most favourable medium for lactic fermentation is a saccharine solution rather more dilute than that used for cultivating yeast, and containing proteins in an incipient stage of decomposition. The analogy between this fermentation and the alcoholic is close, because the two may proceed side by side in the same liquid. The presence of acid is inimical to lactic fermentation; hence the fermentation arrests itself after a time by the development of lactic acid; provided this is neutralised from time to time by the addition of carbonate of lime or magnesia, the fermentation proceeds until the whole of the sugar has disappeared. In a slightly acid liquid, as for instance the juice of the grape, alcoholic fermentation proceeds almost alone; but with wort, which is much more nearly neutral (if made with good malt), lactic fermentation sets in with readiness, and consequently has to be specially guarded against. Some varieties of the lactic acid ferment require air for their growth and development, while others are anaërobic in their character.

In addition to its specific action on glucose, converting it into lactic acid, the lactic ferment has other functions of importance in commercial operations; thus, the presence of lactic ferment germs on malt result in the formation of a little lactic acid during the mashing; in distillers' mashes this is found to be somewhat valuable, and is encouraged, as it apparently helps to effect a more complete saccharification of the malt, and consequently increases the yield of alcohol. It also peptonises the proteins, bringing them into a condition more adapted for the nutrition of yeast. Distillers, therefore, frequently allow their malts to develop considerable acidity before using them, and give new mash tuns a coating of sour milk before bringing them into use. In bread-making, by the Scotch system, the presence of the lactic ferment is deemed to make better bread: either the ferment, or the lactic acid produced, softens and renders the gluten of the flour more elastic.

Hansen's methods have been applied to the preparation of pure cultivations of lactic ferments, with the view of securing a more satisfactory acidification of cream preparatory to its being made into butter. Two distinct species have been isolated, which give particularly favourable results in butter-making; one of these is stated by Storch to give a pure and mild slightly sour taste, imparting at the same time a very pure aroma to the cream and butter made therefrom. There are other lactic acid-forming bacteria, which, on the contrary, produce diseases in milk; thus, one species causes the milk to become viscous at the same time as it undergoes lactic fermentation. Further, certain bacteria induce a tallow-like flavour in butter. Not only may we have a fermentation producing lactic acid as distinct from other acids, but also there are differentiations in the character of the secondary products formed at the same time as the lactic acid, and which secondary products affect most vitally the success or otherwise of the particular process from its manufacturing standpoint. It is more than possible that these variations in the nature of lactic fermentation itself may have a direct bearing on the success of bread-making operations.

344. Butyric Fermentation.—At the close of the lactic fermentation of milk, the lactic acid or lactic salts, as the case may be, seem to be acted on by ferment organisms and converted into butyric acid with the evolution of carbon dioxide and hydrogen—

$$\underset{\text{Lactic Acid}}{2HC_3H_5O_3} = \underset{\text{Butyric Acid}}{HC_4H_7O_2} + \underset{\text{Carbon Dioxide.}}{2CO_2} + \underset{\text{Hydrogen.}}{2H_2}.$$

Several species of *bacteria* are capable of inducing butyric acid fermentation. The most carefully examined among these is *Clostridium butyricum,* known also as *Vibrio butyricus,* which occurs in the form of short or long rods, and is in shape and general appearance very similar to *B. subtilis,* differing, however, from that organism in that it contains starch. In breweries and pressed yeast factories, butyric fermentation is often caused by organisms of altogether different type to *C. butyricum.* This particular organism is anaërobic in character, but others of the species producing butyric acid are distinctly tolerant of oxygen. The general conditions of butyric fermentation are similar to those of lactic fermentation. A temperature of about 40° C. (104° F.) is specially suitable; the presence of acids is to be avoided; or where butyric fermentation is not wished, its prevention is more or less attained by working at a lower temperature and with a slightly acid liquid. However, with the fully developed organism, a slight acidity is unable to prevent butyric fermentation. Although butyric fermentation is usually preceded by lactic fermentation, the butyric ferment is also capable of acting directly on sugar itself, and also on starch, dextrin, and even cellulose.

Tannin has a markedly prejudicial effect on the growth and development of bacterial life, hence the addition of this substance, or any compound containing it, to a fermenting liquid, exercises great preventive action on the development of lactic and butyric fermentation. Hops contain tannin as one of their constituents, and also the bitter principles of the hop cause a hopped wort to be much less liable to lactic fermentation than one unhopped. For a similar reason, bakers add hops to their patent yeast worts.

345. Acetic Fermentation.—Certain organisms effect the change of wine and beer into vinegar. The reaction is one of oxidation of the alcohol present: in the first place, aldehyde is formed, and then this body is oxidised into acetic acid, according to the following equations:—

$$\underset{\text{Alcohol.}}{2C_2H_5HO} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Aldehyde.}}{2C_2H_4O} + \underset{\text{Water.}}{2H_2O}.$$

$$\underset{\text{Aldehyde.}}{2C_2H_4O} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Acetic Acid.}}{2HC_2H_3O_2}.$$

Pasteur described under the name of *Mycoderma aceti* an organism through whose agency alcohol is oxidised into acetic acid. Hansen has detected two distinct species under this name, distinguished by the one staining yellow, and the other blue, with iodine solution. Both possess the same chemical properties, and in order to develop vigorously require a plentiful supply of oxygen. They are, in fact, strictly aërobic. A temperature of about 33° C. is the most favourable to the production of acetic fermentation. *Bacterium aceti* also converts propyl alcohol into propionic acid, but is without action on either butyl alcohol or the amyl alcohol of fermentation.

Bacterium aceti forms a mycelium on the surface of liquids, possessing a certain amount of tenacity: viewed under the microscope, this mycelium is seen to consist of chains of cells, as shown in Plate V.

In the substance known as "mother of vinegar" or the vinegar plant, long supposed to be identical with *B. aceti,* A. J. Brown discovered a separate organism, which, in addition to producing acetic acid, is also marked by the property of causing the formation of cellulose; to this he has given the name of *Bacterium xylinum.*

Peters has discovered in extremely old and sour leaven an acetic acid bacterium, distinct from those just described. The individuals are about 1.6 μ long, and 0.8 μ broad, truncated at one end, and tapering at the other. Interest attaches to the isolation of this specific organism, inasmuch as a small proportion of the acidity of bread is due to acetic acid.

A temperature below 18° C. is almost inhibitory to the action of the acetic acid ferment, while most antiseptics, and especially sulphur dioxide, are exceedingly inimical to acetous fermentation.

Jörgensen remarks that "an important advance was made in our knowledge of acetic bacteria when Buchner and Meisenheimer, as well as Herzog, proved that this remarkable fermentation is brought about by the activity of an enzyme. The cells may be killed with acetone, and then treated in the same way as the alcohol yeasts (see Chapter IX., paragraph 289), and it can then be shown that, after evaporating the liquid, the residue can bring about the acetic fermentation, although it contains no living cells. By this discovery the real nature of the fermentation becomes clear. Like the alcoholic fermentation, it is caused by an enzyme, which may react independently of the living cell that brought it into existence." (*Micro-organisms and Fermentation, Fourth English Edition.*)

346. Viscous Fermentation.—Viscous fermentation is that variety which causes "ropy beer." Pasteur supposed this to be due to an organism consisting of globular cells of from 1.2 to 1.4 μ in diameter, adhering together in long chains. Moritz and Morris, who have devoted particular attention to this subject, disagree with Pasteur's views, and ascribe ropiness principally to a ferment known as *Pediococcus cerevisiæ.* This organism occurs either in pairs of cells or tetrads (i.e., four cells arranged in the corners of a square), diameter of each cell being 0.9—1.5 μ. These organisms are similar in appearance to those marked *b,* Fig. 16. Beer, after having undergone this fermentation, runs from the tap in a thick stream; and in very bad cases, a little, when placed between the fingers, pulls out into strings.

A somewhat similar condition sometimes holds in bread, which then is termed ropy bread; this is discussed very fully in Chapter XVII.

347. Disease Ferments.—The ferments of lactic, viscous, and other than alcoholic fermentation, are frequently called "disease ferments," from their producing unhealthy or diseased fermentations in beer.

348. Spontaneous Fermentation.—In this country, alcoholic fermentation is usually started by the addition of more or less yeast from a previous brewing; it was formerly the custom to allow the fermentation to start of itself. This is said still to be practised in some parts of Belgium in the manufacture of a variety of beer, known as "Faro" beer. In manufacturing such beers, the vats of wort are allowed to remain exposed to the air, and fermentation is excited by any germs of yeast that may find their way therein. It is possible that under such circumstances a wort may only be impregnated by yeast germs, in which case pure alcoholic fermentation alone will be set up. It is far more likely, however, that germs of lactic ferment and other organisms will also get into the wort; consequently the beer will be hard or sour, and also likely to speedily become unsound. On the other hand, grape juice is always allowed to ferment spontaneously, but then this liquid is distinctly acid, through the presence of potassium bitartrate; and acidity retards or prevents bacterial fermentation.

Bakers' barms or patent yeasts are at times allowed to ferment spontaneously; they are then found to contain a large proportion of foreign organisms, principally the lactic ferment. Except where very special precautions are adopted, they are liable to be uncertain in their action, and often produce sour bread.

But in all cases of so-called "spontaneous" fermentation it must be remembered that the fermentation is due to the presence in the wort of yeast cells or spores that either have been introduced along with the malt and hops without being destroyed, or else have found their way into the wort from some external source, such as germs floating in the air. It is also frequently possible that a sufficient quantity of yeast remains about the fermenting vessel from the last brewing to again start fermentation.

MOULDS AND FUNGOID GROWTHS.

349. The nature of these has been already referred to in Chapter IX. and the mould of beer, *Mycoderma cerevisiæ,* described and its properties explained. The moulds are all of them members of the fungus family. A few other varieties, because of their having more or less connection with the subject of this work, require description.

350. Penicillium Glaucum.—This is the ordinary green mould of bread, jam, etc. The base of this consists of a mycelium bearing both submerged and aerial hyphæ. The upper ends of the aerial hyphæ terminate in a string of conidia or spores, which break off on the slightest touch; these constitute the green powder which gives this mould its characteristic appearance. One of these spores, on being sown in an appropriate medium, as hay infusion or Pasteur's fluid, germinates and produces a young *penicillium.* The conidia retain their vitality for a long time, and from their extreme minuteness are readily carried about by the air; hence substances that offer a suitable medium for the growth and devlopment of moulds, become impregnated on being exposed to the atmosphere.

Under favourable circumstances *penicillium* developes with extreme rapidity; some few years since the barrack bread at Paris was attacked by this fungus, a few hours was sufficient for its development, and the mould was in active growth almost before the bread was cold. It is stated that the spores of this species are capable of withstanding the heat of boiling water, so that the act of baking an infested flour would not necessarily destroy the spores.

351. Aspergillus Glaucus.—This is another mould very similar to *penicillium* in appearance and colour, but having at the ends of its hyphæ small globose bodies containing the spores; these bodies being termed sporangia.

352. Mucor Mucedo.—This mould develops well on the surface of fresh horse dung; this substance, if kept warm, will be found after two or three days covered with white filaments, these being the hyphæ, and terminating in rounded heads or sporangia. In form *M. mucedo* somewhat resembles *A. glaucus,* but is distinguished from it by having a whitish aspect, *A. glaucus* being of a greenish colour.

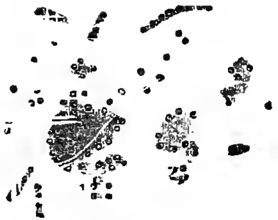


Fig. 19.—*Micrococcus prodigiosus*, Cohn × 1200 (from nature).

353. Micrococcus Prodigiosus.—This organism consists of round or oval cells, from 0.1 to 1 mkm. diameter. These are at first colourless, but gradually assume a blood-red tint: they grow on wheat-bread, starch paste, etc. *M. prodigiosus* is the cause of the appearance known as blood-rain occasionally seen on bread: at times the growths proceed so far as to produce dripping blood-red patches on the bread.

354. Red Spots in Bread.—A phenomenon sometimes confused with the effect of *M. prodigiosus,* but nevertheless quite distinct therefrom, is that of intensely red-coloured spots in freshly baked bread. These are so bright as to lead to the suspicion that concentrated tincture of cochineal or other powerful dye had by accident got on to the dough and been baked with it. Fortunately for the baker, the occurrence of these spots is rare, and consequently there are few opportunities of minutely investigating them. So far as the authors' experience goes, the spots occur most frequently in bread made from flour of the very highest class, such as Hungarian patents: they have also seen them in bread containing a large admixture of Oregon flours. The spots in bread do not increase in size as the bread grows old, nor are they apparently associated with any change in its constituents: there are no signs, in fact, of the colouration being due to the presence of any living and multiplying organism. It is exceedingly difficult to obtain specimens of the colour spots in unbaked dough, and only on one occasion has such a specimen come into the hands of one of the authors. In that case a small batch of dough was sent him while absent from home, and was only examined by him on his return after two days. The dough had then got a slight dry skin on, but there were no signs of any growth or spreading in the dough; so far, therefore, as any conclusion may be drawn from this, it is against the source of colour being any organism developing in the dough. Careful microscopic examination of coloured portions of the bread show in the fainter spots that while the starch is uncoloured, there is a red dyeing of the gluten. In the larger and darker spots there may be sometimes seen by the naked eye a nucleus, which is so dark in colour as to be almost black. On breaking down a little of this nucleus with water, and examining microscopically, the author has invariably found fragments of the outer integument of the grain. Among these have been detected portions of the outside layer of bran, showing its characteristic markings, and also hairs of the beard of the wheat, all of which are intensely coloured. In one sample, only cursorily examined some years ago, a number of filaments somewhat similar to cotton-wool were observed, but not identified; these, too, were coloured to a very deep red. No signs of fungus spores or other special organisms were observable, but spores might possibly be crushed in the breaking down with water. The lack of material for purposes of further examination has prevented the author from carrying these investigations beyond this point, and such tests as are here recorded were made a number of years ago. The most probable cause of the colour is its deposit on the outside of the grain after its removal from the husk and prior to its being milled. It is suggested as its possible source either some insect of the cochineal species, or an intensely coloured microscopic vegetable growth, such as a mould. These minute particles of outer bran carrying the colour on the surface are sufficiently fine to pass through the dressing silks, and so get into the flour. They would be so small as to be perfectly invisible in any ordinary examination by the naked eye. On being wetted the colour spreads and stains the surrounding gluten, hence the colour in the dough, which remains also and is seen most distinctly in the baked bread.

355. Musty and Mouldy Bread.—Mouldiness may be very often noticed in bread which has been kept for a few days: at times a loaf of one day's production will remain quite sound, while another will rapidly become mouldy. The *Analyst, October,* 1885, contains an article by Percy Smith, giving an account of some experiments made by him on musty bread. The bread when new had no disagreeable taste, but on the second day had become uneatable. Smith made a series of experiments, among which were the following:—

(*a*) Musty bread, one day old, soaked in water, enclosed between watch glasses.
(*b*) Flour from which the bread was made, similarly treated.

In six days *a* had begun to turn yellow, emitted a disagreeable odour, and began to assume a moist cheesy consistency and appearance. This portion was found to be swarming with *bacteria.* On *b, mucor mucedo* grew in abundance; the flour ultimately dried up without further change.

(*c*) Sweet bread similarly treated.

Aspergillus glaucus appears, but no *mucor,* neither does the bread become cheesy nor evolve odour of musty bread. The following are Smith's conclusions based on these and other experiments.

"Ordinary bread turns mouldy owing to the growth of *A. glaucus.* Musty bread, on the other hand, yields both *A. glaucus* and *M. mucedo,* and then undergoes putrefactive decomposition, becoming the home of *vibriones* and *bacteria.* These organisms, of course, can have nothing to do with the mustiness; they only flourish because there is a suitable nidus for their growth. It is, however, curious that the musty bread should decay while the sweet bread should not, whilst the only *apparent* difference between them is in the growth of *M. mucedo.* The suspected flour produces an abundant crop of *mucor,* but does not decay. This is no doubt due to the fact that starch is not so suitable a nidus as is dextrin for *bacteria.* Perfectly pure flour failed to decompose when kept between watch glasses, but when placed in a damp cellar readily became musty, and produced a crop of *M. mucedo.*" He further concludes that this fungus is the cause of the mustiness in the cases cited, although other species may possess similar properties. When the flour was baked into bread, the assimilation of moisture regenerated the fungus, thus causing the bread to become musty, for which result it is not necessary for the plant to arrive at maturity; the disagreeable taste being developed as soon as flocci are visible under the microscope. *Mucor* has apparently a specific chemical action on bread that is not possessed by *Aspergillus glaucus.*

Hebebrand has recently published the results of some investigations on mouldy bread. He infected some samples of rye bread from mouldy bread, the organisms being chiefly *Penicillium glaucum* and *Mucor mucedo.* These were kept for periods of seven and fourteen days, and similar samples at once dried for analysis. The results showed that the mould caused a considerable loss of substance, carbohydrate being converted into water and carbon dioxide. There was only a slight loss of proteins, but the loss of carbohydrates caused the percentage of proteins to appear much higher in the dry substance of the mouldy bread. The decomposed protein was converted into amides. The following numbers show the percentage composition (1) of dried fresh bread, and (2) of the dried mouldy bread:—

	No. 1.	No. 2.	
Protein, Insoluble	9.75 per cent.	9.77 per cent.	
„ Soluble	1.92 „	5.15 „	
Maltose	1.54 „	0.50 „	
Dextrin	8.02 „	11.86 „	
Starch	76.75 „	63.52 „	
Fat	0.26 „	2.11 „	(?)
Ash	1.44 „	2.41 „	
Crude Fibre	0.05 „	2.47 „	

356. Diseases of Cereals.—Certain diseases to which the cereal plants are subject are due to parasitic fungoid growths. Among these are mildew, smut, bunt, and ergot. Their nature may briefly be considered at this stage of our work.

357. Mildew.—To the farmer this blight is unhappily too familiar; if a wheat field be examined in May or June, a greater or less number of the plants will appear as though some of the lower leaves had become rusty; at the same time the leaves are sickly and atrophied. As the disease develops the number of rusty leaves increases; the "rust" itself will be found on examination to consist of the spores of a fungus, known as the *Puccinia graminis* or corn mildew. The mycelium penetrates the tissues of the leaves, occupying the intercellular spaces, and thus gradually destroys them, with the effect of seriously injuring and reducing the corn crop.

Shutt collected by hand on the same day in the same field samples of rust-free and rust-attacked wheat. The former have a normal ear both as to size and colour, and a plump, well-filled grain. The straw of the latter showed many spots of infection, while the ears were smaller than normal and the grains light and much shrivelled. The following are the results of analysis of the two samples of wheat:—

	Rust-free.	Rusted.
Weight of 100 grains in grams	3.0504	1.4944
Water per cent.	12.26	10.66
Crude Protein „	10.50	13.69
Crude Fat „	2.56	2.35
Carbohydrates „	70.55	68.03
Fibre „	2.29	3.03
Mineral Matter „	1.84	2.24

The protein is considerably higher in the rusted grain, a result probably due to the fact that protein is first lodged in the grain during the processes of metabolism, and afterward the carbohydrates. A result of rust attack is that the maturation of the grain is retarded, and the lodgment of starch is incomplete. But though the total protein is high, the wheat will probably be found to be lacking in strength (*Jour. Amer. Chem. Soc.*, 1905, 366).

358. Smut.—This disease is also known as "dust brand," "chimney sweeper," and by other names all referring to the black appearance of ears of grain infested by it. When the grain is nearly ripe, there will be noticed here and there in a wheat field shrivelled looking ears, which look as though covered with soot. Smut is due to a fungus which has received the name of *Ustilago segetum*. The fungus develops within the seeds, destroying the contents of the grain, and replacing them by a mass of spores which appear as a fine brownish black powder. Smut is a very destructive parasite, and attacks barley, oats, and rye, and also, although to a somewhat lesser extent, wheat. Viewed microscopically, the spores of *U. segetum* are found to be spherical, and to have a diameter of about 8 mkms.; their appearance is shown in the following figure.

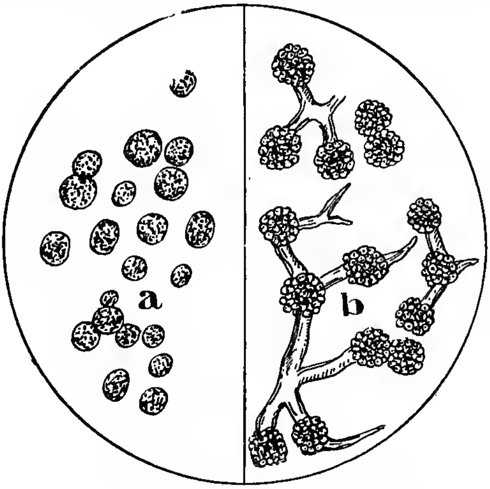


FIG. 20.—*a*, Smut, *b*, Bunt × 400 diameters.

359. Bunt or Stinking Rust.—Unlike smut, bunt produces no external signs of its presence in a wheat field: there is no sooty appearance of the ear, nor any rust above the leaves. It is not until the wheat is threshed from the straw that the bunted grains are discovered in the sample. Externally, these grains are plumper than those which are sound; but on their being broken, the interior, instead of being white and flour-like, is found to be filled with a black powder, having a greasy feel when rubbed between the fingers, and a most fœtid and unpleasant odour. This dust consists of the spores of a fungus termed *Tilletea caries*, mixed with portions of its mycelium. The spores are much larger than those of smut, and, viewed under the microscope, appear as shown in Fig. 20: they are about 17 mkms. in diameter.

The presence of bunt is said not to affect the wholesomeness of flour; it is stated that bunted flour is at times made up into gingerbread; the other condiments used masking its colour and odour. With the extreme care manifested in modern systems of milling, it is improbable that bunt often finds its way into the flour.

360. Ergot.—This disease is almost exclusively confined to rye; like bunt and smut, ergot is due to a fungus which develops within the grain, filling its interior with a compact mass of mycelium and spores, and altering the starch cells by replacing the amylose with a peculiar oily matter. This fungus is termed *Oidium abortifaciens*. The ergotised grains are violet-brown or black in colour, moderately brittle; and when in quantity evolve a peculiar nauseous fishy odour, due to the presence of trimethylamine. Ergot possesses powerful medicinal effects, and when taken in anything over medicinal doses, acts as a violent poison. The presence of ergot in flour is therefore extremely dangerous.

Chemical tests for the detection of ergot and moulds will be given in the analytic section of this work.

Experimental Work.

361. Prepare some malt wort; filter and allow the liquid to remain for some days in an open flask. In about 24 hours the liquid becomes turbid; examine a drop under the microscope with the highest power at disposal. *Bacteria* will be seen in abundance; notice that they have a distinct migratory movement. Examine a sample each day, and observe that the *bacteria* grow less active, and ultimately become motionless; they have then assumed the zooglœa stage. Carefully search the liquid for other organisms; *bacilli* should be detected, being recognised by their filamentous appearance. *Vibrios* should also be observed; they appear very like *bacilli,* except that they have bent joints. When actively moving they exhibit an undulatory movement, depending on their rotation on their long axis.

Examine microscopically some of the sediment of "turned" beer; large quantities of *bacilli* can usually be observed. These organisms are also commonly found in bakers' patent yeasts.

Place some fresh clear wort in a flask and plug the neck moderately tightly with cotton-wool; boil the liquid for 5 minutes and allow to cool: notice that the contents of the flask remain clear. At the end of a week, remove the plug and examine a drop of the liquid under the microscope, *bacteria* and other organisms are absent. The wort is still sweet and free from putrefactive odour. Let the flask now stand freely open to the atmosphere: organic germs gain entrance, and putrefactive or other changes rapidly occur. On the next and succeeding days, examine microscopically.

Procure a small quantity of milk and allow it to become sour; examine microscopically for *Bacterium lactis.* Also, wash a few grains of malt in a very little water, and examine the washings for this organism.

Prepare two samples of wort, strongly hop the one by adding hops in, the proportion of one-tenth the malt used: boil the two samples, filter and set aside under precisely the same conditions. Observe the relative rate of growth and development of bacterial life in the two.

CHAPTER XI.

TECHNICAL RESEARCHES ON FERMENTATION.

362. In this chapter are contained the results of certain technical researches made by the authors and others on matters having a more or less direct bearing on bread-fermentation.

363. Strength of Yeast.—To the baker, the first consideration about yeast is its strength or gas-yielding power: there are other effects which it also produces, but its all-round activity may be fairly measured by the quantity of gas it evolves from a suitable saccharine medium. The term "strength" is therefore used in this sense; it follows that the strongest yeast will also raise bread better, because the rising of the dough is due to the gas evolved by the yeast from the saccharine constituents of the flour. Different modes have been adopted from time to time for the purpose of testing the strength of yeast. The essential principle of these has been to ferment a definite quantity of some saccharine fluid with a constant weight of yeast, at a constant temperature, and to then determine the volume of gas evolved in a given time.

The reader is already aware that water is capable of dissolving carbon dioxide gas to the extent of its own volume; this, therefore, is an obstacle to the employment of water for its collection. One of the authors, nevertheless, made the experiment, and found that on collecting the gas evolved by the yeast during fermentation, in the ordinary manner in a graduated gas jar over water, most interesting results could be obtained. These were of course not absolutely correct, because a certain quantity of the gas was absorbed by the water; still, duplicate experiments gave corresponding quantities of gas, while most important information was gained as to the general character of different yeasts when examined in this manner. Results obtained in this way may therefore be viewed as comparable with each other.

364. Yeast Testing Apparatus.—In the next place a series of experiments were made in which the gas was admitted to the graduated jar through the top, and so did not bubble through the water at all. When collected in this way the amount of absorption was small and very uniform. Two jars were two-thirds filled in this manner with washed carbon dioxide gas prepared from marble and hydrochloric acid. They were then allowed to stand, and the amount of absorption observed hourly. The rate of absorption, with the particular jars used, was as nearly as possible a cubic inch per hour. Subsequent trials with jars of one hundred cubic inch capacity gave an outside rate of absorption of two cubic inches per hour. A still better plan is to use instead of water an aqueous solution of calcium chloride of a degree of concentration giving a specific gravity of 1.4. With this solution there is practically no absorption of carbon dioxide. A saturated solution of common salt (brine) may be used instead of the calcium chloride, with only slightly more absorption. As a result of numerous experiments, the authors employ one or other of the forms of apparatus shown on the following page.

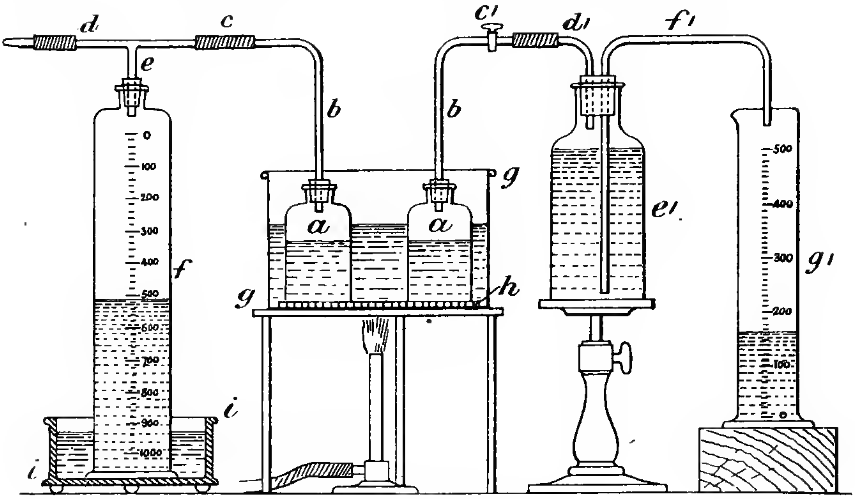


FIG. 21.—Yeast-Testing Apparatus.

The glass bottle, marked *a* in the figure, is of about 12 ounces capacity, and is fitted with india-rubber cork and leading tube, *b*. The sugar or other saccharine mixture to be fermented is raised to the desired temperature, and then placed in this bottle. The yeast is weighed out, and then also added; they are then thoroughly mixed by gentle agitation. By means of an india-rubber tubing joint at *c*, the generating bottle is connected to the leading tube, *e*, of the glass jar, *f*. This leading tube is provided at *d* with a branch tube, which may be opened or closed by means of a stopper of glass rod and piece of india-rubber tubing. The jar, *f*, is graduated, as shown, into cubic centimetres commencing immediately below the shoulder with 0, and ending near the bottom with 1000. This constitutes the apparatus proper; in use the generating bottle, *a*, is placed in a water-bath, *g g*. This bath is fixed on a tripod over a bunsen burner, and is provided with an iron grid, *h*, in order to prevent the generating bottle coming in absolute contact with the bottom of the bath. By means of an automatic regulator the bath is maintained at any desired temperature. The gas jar, *f*, stands in a pneumatic trough, *i i*.

As a rule, more than one test is made at a time, the water-bath should therefore be sufficiently large to take four or six bottles at once: two pneumatic troughs are then employed, and either two or three of the gas jars, *f*, arranged in each. While for strictly accurate experiments it is essential that the yeast bottles be kept as nearly as possible at a definite temperature, yet results of interest may be obtained without the employment of a water-bath. The whole apparatus should, under those circumstances, be placed in some situation where, as nearly as possible, a constant temperature is maintained.

At the start of the experiment the air is exhausted through *d*, which is again closed with the stopper. As the fermentation goes on the gas evolved is collected in *f*, and its volume read off, from the surface of the water, at the end of each half-hour or hour. Full and detailed particulars are given at the end of this chapter as to the exact mode of procedure in using this apparatus.

When the requisite allowance is made for the absorption of the gas by water, the corrected reading very nearly corresponds with the absolute amount of gas which has been evolved. It is far better, however, to use brine and so prevent any absorption of the gas. There are slight variations due to alterations of barometric pressure and of temperature; these can, if wished, be calculated out and allowed for—that is not, however, for ordinary purposes necessary. Gases are usually measured at a standard pressure of 760 millimetres, or very nearly 30 inches of mercury, that is with the barometer standing at 30. A rise or fall of the barometer through half an inch only makes a difference of one-sixtieth on the total reading, and this may as a rule be neglected. In case the estimation is being made in either the laboratory or a bakehouse, the temperature is, as a rule, fairly constant. Supposing it be taken at 70° F., then it will be found that a difference of 5° either way only causes a variation in the volume of the gas of one hundredth the total amount. Barometric and thermometric variations may, therefore, for most practical purposes, be neglected. Further, whatever variations there may be either in temperature or pressure, all the tests made at the same time are made under precisely similar conditions.

In all the experiments quoted, except the later ones, the gas was collected over water. No corrections were, however, made for absorption, because it is evident that at the outset the carbon dioxide remains as a layer of gas within the bottle, simply displacing air over into *f*; during this time no absorption can take place. It should, however, be remembered that, when the gas remains stationary for any length of time, a quantity must have been evolved about equal to that being absorbed.

In the alternative apparatus, the generating bottle, *a*, and leading tube, *b*, are the same as before. At c^1, a glass stop-cock is fixed in the leading tube which is attached by means of india-rubber tubing to d^1, the further end of which just passes through an india rubber cork fixed in the glass bottle, e^1, having a capacity of 600 c.c. or thereabouts. Another tube, f^1, leads from the bottom of e^1, and has its lower end open. Under this is placed a graduated measuring jar, g^1, of 500 c.c. capacity. In use the yeast and fermenting medium are placed as before in the generating bottle, *a*. The bottle e^1 is filled with brine, and the apparatus fixed together and arranged in position as shown in the figure. As gas is generated in the bottle, *a*, it displaces an equivalent amount of brine in e^1, the liquid passing over and being collected in the measuring jar, g^1. Readings of the volume of brine thus displaced may be made hourly, and thus results obtained of a similar character to those with the other apparatus. When the collecting jar is filled to the 500 c.c. mark, the stop-cock, c^1 may be closed and the brine in g^1 returns to e^1, and the collection and measurement of gas again commenced on reopening the stop-cock, c^1. This second form of apparatus can be the more readily fixed up from appliances found in the laboratory, while both are practically identical in their working. In the first form, the gas within is under diminished pressure, any leakage therefore will increase the apparent amount of gas evolved. In the second arrangement, the gas is under increased pressure, and consequently any leakage will result in loss of gas.

365. Degree of Accuracy of Method.—This is a matter of great importance, because unless fairly constant and accurate results are obtainable, little or no confidence can be placed in them, or any deductions based thereon. A number of duplicate experiments were therefore first made in order to test the accuracy of the estimations; the results are appended. They serve also to show how the results may be entered up in the laboratory note-book. For the composition of "Yeast mixture," see paragraph 367:—

No. 1, Brewer's Yeast, ½ oz.; Yeast Mixture, ½ oz.; Water, 6 oz. at 30° C.
No. 2. Duplicate of No. 1.
No. 3. French Compressed Yeast, ¼ oz.; Yeast Mixture, ½ oz.; Water, 6 oz. at 30° C.
No. 4. Duplicate of No. 3.

Time.	Gas Evolved in Cubic Inches.								Temperature.
	No. 1.		No. 2.		No. 3.		No. 4.		
0	0.0		0.0		0.0		0.0		29.7
		0.7		0.5		3.1		2.5	
½ hour	0.7		0.5		3.1		2.5		30.0
		5.8		5.5		16.1		15.2	
1 „	6.5		6.0		19.2		17.7		30.0
		7.7		7.8		21.8		21.4	
1½ hours	14.2		13.8		41.0		39.1		29.8
		7.8		8.2		21.0		20.7	
2 „	22.0		22.0		62.0		59.8		28.9
		8.0		7.7		20.0		20.4	
2½ „	30.0		29.7		82.0		80.2		29.5
		11.0		11.3		21.5		21.0	
3 „	41.0		41.0		103.5		101.2		30.0
		6.0		5.7		22.3		23.2	
3½ „	47.0		46.7		125.8		124.4		30.25
		7.5		8.0		17.8		20.4	
4 „	54.5		53.7		143.6		144.8		30.25
						14.9		15.9	
4½ „	—		—		158.5		160.7		30.0
						9.5		9.3	
5 „	—		—		168.0		170.0		30.0
						7.0		5.0	
5½ „	—		—		175.0		175.0		30.0
						2.8		0.8	
6 „	—		—		177.8		175.8		29.9

The figures placed opposite the brackets represent the volume of gas given off in each successive half-hour. A thermometer was placed in the water-bath and the temperature observed at the time of each reading, and registered in the last column. The temperature in this experiment shows considerably greater variations than that in those made later. It will be noticed that both pairs of duplicates agree very closely throughout the entire fermentation.

It may here be mentioned that a half-ounce of sugar yields, on the supposition that the whole is transformed into carbon dioxide and alcohol, the following quantities:—

½ oz. of sugar = 14.2 grams, and yields 7.30 grams of CO_2 =
3.705 litres = 226 cubic inches at 0° C. =
242 " 20°C.
(One cubic inch = 16.4 c.c.)

It will be remembered that actually only about 95 per cent. of the sugar is thus converted into carbon dioxide and alcohol; these quantities in strictness, therefore, require to be reduced about 5 per cent.

As in the experiments to be now described the same brand or kind of yeast was used on different days, it was necessary, as a preliminary, to ascertain the degree of constancy of strength of the same yeast. Determinations were made on one brand of compressed yeast with the following results:—

No. 1.—April 27, 1885,
No. 2.—May 7, 1885,
No. 3.—June 30, 1885,
} Yeast, ¼ oz.; Yeast Mixture, ½ oz.; Water, 6 oz. at 30° C.

Time.	Gas Evolved in Cubic Inches.					
	No. 1.		No. 2.		No. 3.	
0	0.0		0.0		0.0	
		21.7		24.5		28.7
1 hour	21.7		24.5		28.7	
		41.3		36.4		31.9
2 hours	63.0		60.9		60.6	
		33.0		43.1		43.6
3 "	96.0		104.0		104.2	
		34.3		32.0		40.8
4 "	130.3		136.0		145.0	
		24.2		22.5		30.0
5 "	154.5		158.5		175.0	
		15.7		17.5		2.8
6 "	170.2		175.0		177.8	

Although these results do not agree with that closeness observable in the duplicates, yet it will be seen that the yeast is throughout fairly similar in behaviour; still, it must be remembered that in experiments made on different days the results are not always strictly comparable, because the yeast is sure to be not absolutely the same in each case.

366. Effect of Different Media on Yeast Growth.—That certain substances are eminently fitted for aiding the growth and development of yeast, while others are not so suited, has already been stated. In order to measure quantitatively the effect of sowing yeast in different solutions, the following determinations were made.

367. Comparison between Sugar, "Yeast Mixture," Pepsin, and Albumin.—The "yeast mixture" referred to is based on the fluid in which Pasteur cultivated a yeast, and which is known as "Pasteur's Fluid." Pasteur employed a solution of sugar and ammonium tartrate to supply saccharine matter and nitrogen; to this he added some yeast ash as a source of mineral constituents. This fluid may be closely imitated by use of the following formula—

Potassium Phosphate	20 parts
Calcium Phosphate	2 „
Magnesium Sulphate	2 „
Ammonium Tartrate	100 „
Purest Cane Sugar	1500 „
Water	8376 „
	10,000 parts

As this solution keeps badly, the yeast mixture consists of Pasteur's Fluid, *minus* the water. The salts are first powdered and dried, and then mixed until thoroughly incorporated. This mixture has the great advantage that while dry it can be kept any length of time without change.

Date, April 26, 1885.

No. 1 Pure sugar, ½ oz. (14.2 grams[1]); compressed yeast, ⅛ oz. (3.5 grams); water, 6 oz. (170 grams) at 30° C.

No. 2. Yeast mixture, ½ oz.; compressed yeast, ⅛ oz.; water, 6 oz. at 30° C.

No. 3. Pure sugar, ½ oz.; pepsin, 1.5 grams; compressed yeast, ⅛ oz.; water, 6 oz. at 30° C.

No. 4. Yeast mixture, ½ oz.; pepsin, 1.5 grams; compressed yeast, ⅛ oz.; water, 6 oz. at 30° C.

At the expiration of seven hours, the following quantities of gas had been evolved:—

No. 1.	51.3 cubic inches.	No. 3	112.0 cubic inches.
No. 2.	132.0 „	No. 4	181.5 „

Experiments were also made with pepsin and albumin by themselves, but neither of these gave practically any evolution of gas.

From these experiments the following conclusions are derived:—

Pure sugar undergoes a regular but somewhat slow fermentation.

Sugar mixed with about ten per cent. of pepsin ferments at first more slowly, but afterwards much more rapidly.

"Yeast mixture," consisting of sugar, ammonium tartrate, and inorganic salts, ferments from the commencement still more rapidly.

Yeast mixture, with about 10 per cent. of pepsin, undergoes still more rapid fermentation.

Nitrogenous bodies alone, as pepsin, albumin, in water, or 2½ per cent. salt solution, evolve practically no gas.

Pepsin and other nitrogenous bodies must therefore be considered, not as the substances from which yeast causes the evolution of gas, but as stimulating nitrogenous yeast foods.

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[1] In these experiments an anomaly will be noticed in the systems of weights employed. In deference to the fact that many of the readers of this book will be much more familiar with the English than the metric weights and measures, the authors have, where practicable, used the former system.

The relation between grams and fractions of an ounce may be understood by remembering once for all that

1 ounce or 16 drams = 28.35 grams.
½ „ „ 8 „ = 14.2 „
¼ „ „ 4 „ = 7.1 „
⅛ „ „ 2 „ = 3.5 „

368. Comparison between Filtered Flour Infusion, Wort, and Yeast Mixture Solution.—Pursuing the same line of investigation, experiments were next made for the purpose of examining and comparing flour infusion, wort, and yeast mixture, as fermentable substances. An infusion of flour was made by taking 400 grams of flour, and 1000 c.c. of water; these were shaken thoroughly in a flask, from time to time, for half an hour, and then allowed to subside: the clear liquid was filtered, and its specific gravity taken; this amounted to 1007.2. Meantime, some malt wort had been prepared; this was divided into two portions, the one of which was boiled, the other allowed to remain at the mashing heat. These were next cooled, and each diluted down until the specific gravity coincided with that of the flour infusion. A solution of yeast mixture of the same density was also prepared. Fermentation was started in each of these with the results given in the following table:—

Date, May 8, 1885.

No. 1. 40 per cent. filtered flour infusion, Sp. G. 1007.2, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 2. Unboiled malt wort, Sp. G. 1007.2, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 3. Boiled wort, Sp. G. 1007.2, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 4. Yeast mixture and water, Sp. G. 1007.2, 6 oz. at 30° C.; compressed yeast, ¼ oz.

At the end of five hours, the following quantities of gas had been evolved:—

No. 1	8.3 cubic inches.	No. 3	18.2 cubic inches.
No. 2	17.1 „	No. 4	24.3 „

The flour infusion evolved gas but slowly, and toward the end of five hours, over which the experiment lasted, had fallen off considerably. The two malt infusions yielded carbon dioxide at about double the speed; that in the boiled wort being the higher. The greater quantity of gas in the latter instance is due to the fact that boiling coagulates some of the proteins of the wort, and so leaves a greater percentage of sugar in the liquid, when both are diluted to the same density. This is an interesting instance of the removal of proteins resulting in a more copious and rapid evolution of gas. The yeast mixture causes the carbon dioxide to be evolved with still greater rapidity. Summing up the results:—

In solutions of the same density,

Flour infusion, on fermentation, yields gas somewhat slowly;

Unboiled wort, at about double the speed;

Boiled wort, slightly more rapidly than the unboiled; and

Yeast mixture solution, at about three times the rate of the flour infusion.

The soluble extract of flour is thereby shown to be capable of only a slow fermentation; this is due to its containing a comparatively low proportion of sugar, and much of that of a kind which requires to be inverted before it can be fermented.

369. Comparison between Flour and its Various Constituents fermented separately.—From the baker's point of view, it is of very great importance that he should know which of the several constituents of flour it is that affords, during fermentation, the gas by which his dough is distended. The following experiments were made for the purpose of obtaining definite information on this subject—No. 1 requires no further explanation. In No. 2, 34 grams of flour were mixed with 6 oz. (=170 c.c.) of water, being equivalent to 20 per cent. of flour in the water. In No. 3, the flour was agitated several times with large quantities of water, and allowed to subside between each washing, the supernatant liquid being poured off, and only the insoluble residue retained. In this manner, the washed insoluble residue is obtained comparatively free from the other constituents. Of these three samples, No. 2 represents the whole of the flour, No. 1 the soluble, and No. 3 the insoluble portion. No. 4 consisted of 20 per cent. flour infusion, with gelatinised starch added; the whole being subjected to a temperature of 30° C. for 12 hours before fermentation: this method was adopted in order to determine what diastatic effect was produced by the flour infusion on the gelatinised starch, it being assumed that whatever starch was converted into sugar would, under the influence of the yeast, be decomposed with the evolution of carbon dioxide gas. No. 5 was a somewhat similar experiment, made with gluten; some flour was doughed, and then the gluten washed as well as practicable in a stream of water. In order to get as large a surface as possible, this gluten was next rubbed in a mortar with clean sand; it was in this way cut up into a ragged mass. The gluten was mixed with water and kept at 30° C. for 12 hours, in order to permit any degrading action, that warm water is capable of exerting on gluten during that time to assert itself. In Nos. 4 and 5, yeast was added at the end of 12 hours. No. 6 was a repetition of No. 4, except that the gelatinised starch and flour infusion were mixed immediately before fermentation. In No. 7 the starch was simply added to the flour infusion without previous gelatinisation. No. 8 consisted of wheat-starch and water only, to which yeast was added. The starch used for these experiments was specially prepared in the laboratory from the best Hungarian flour by washing the dough, enclosed in muslin, thus separating the gluten. The starch was allowed to settle, and the supernatant liquid poured off; the starch was then stirred up with some more water, and again allowed to subside. These washings were repeated daily for about a fortnight, at the end of which time the starch was air-dried. On being tested with Fehling's solution the starch gave no trace of precipitate: its purity was therefore assured. This series of fermentation tests altogether extended over a period of three days.

Date, May 11, 1885.

No. 1. 20 per cent. filtered infusion of flour, 6 oz. at 30° C., compressed yeast, ¼ oz.

No. 2. 34 grams flour; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 3. Washed insoluble residue from 34 grams of flour: water, 6 oz. at 30° C.; compressed yeast, ¼ oz.

Date, May 12, 1885.

No. 4. 20 per cent. filtered flour infusion, 6 oz. at 30° C.; wheat starch, 5 grams taken and gelatinised, cooled, then added to flour infusion. Mixture placed in bottle and maintained at 30° C. for 12 hours; then ¼ oz. compressed yeast added and fermentation commenced.

No. 5. Moist thoroughly washed gluten, 5 grams, triturated in mortar with sand in order to expose large surface: gluten with 6 oz. of water at 30° C. placed in bottle and maintained at 30° C. for 12 hours; then ¼ oz. compressed yeast added and fermentation commenced.

Date, May 13, 1885.

No. 6. 20 per cent. filtered flour infusion, 6 oz. at 30° C.; wheat starch, 5 grams, gelatinised; compressed yeast, ¼ oz.

No. 7. 20 per cent. filtered flour infusion, 6 oz. at 30° C.; wheat starch, 5 grams, ungelatinised; compressed yeast, ¼ oz.

Date, May 11, 1885.

No. 8. Wheat starch, 5 grams, gelatinised, water 6 oz. at 30° C.; compressed yeast, ¼ oz.

At the expiration of six hours, the following quantities of gas had been evolved:—

No. 1	2.5 cubic inches.	No. 5	1.3 cubic inches.
No. 2	17.5 ,,	No. 6	33.7 ,,
No. 3	3.0 ,,	No. 7	8.2 ,,
No. 4	37.5 ,,	No. 8	0.9 ,,

No. 1, consisting of 20 per cent. flour infusion, gave off very little gas, the quantity amounting to only 2.5 cubic inches in six hours; this is very much less than that obtained in the previous series of experiments in which a 40 per cent. infusion was employed; the latter gave off 8.3 cubic inches in five hours. No. 2, containing the whole of the flour, gave off gas much more copiously, in six hours there being 17.5 cubic inches of gas evolved. After the second hour, the evolution fell off slowly but regularly.[1] The washed residue gave off just the same amount of gas as did the filtered infusion; in fact, at the end of the fifth hour, No. 3 gave the higher reading. It will be noticed that the whole of the flour gives off three times as much gas as do the filtered infusion and the washed residue together. The reason is that, when flour is shaken with water and then filtered, the substances which under the action of yeast evolve gas are not all removed in the filtrate: they are only separated from the insoluble residue with great difficulty, and several washings do not so thoroughly remove fermentable matter as to leave the residue completely unfermentable. That the fermentation in No.3 is not due to the insoluble residue is proved by the result of experiment No. 5; for with well washed and kneaded gluten, but very little gas is evolved, the total amount in nine hours being only 1.5 cubic inches, and this although the gluten for twelve hours previous to fermentation was digested with water at 30° C. Much of the fermentable matter of flour belongs to what may be called the semi-soluble portion, that is, the part of the flour which is retained by an ordinary filter paper, but on kneading is readily separated by the mechanical action from the gluten. In Nos. 4 and 6 the quantities used are the same, but the former of the two samples affords evidence of diastasis having been occasioned during the twelve hours for which the gelatinised starch was subjected to the action of the flour infusion. No. 6 at first proceeded somewhat the more rapidly, but evolved very little gas during the second hour; during the third hour, however, it recovered itself and proceeded regularly, until at the expiration of six hours the evolution of gas ceased, with a total of 33.7 inches. In No. 4 the fermentation proceeds rapidly and regularly, falling off towards the end, and finishing at five hours with 37.5 cubic inches. As a result of the previous diastasis, a larger quantity of gas is evolved, but in each instance the greater part of the starch remained behind, as if 5 grams of starch were

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[1] In all these tests, readings were made either every hour or half-hour, but usually the result of one reading only is here given. When of special interest, however, the explanatory remarks contain also references to other readings.

completely changed into sugar, and then by fermentation into carbon dioxide and alcohol, the yield of gas would roughly be about 85 cubic inches at 20° C. The diastatic action of the flour infusion will have more or less effected the hydrolysis of the starch into dextrin and maltose; the latter will have undergone fermentation, while the former is unfermentable. Experiment No. 8 shows that the diastasis of the starch is effected by the flour infusion, and not by the yeast, for where pure gelatinised starch and yeast alone are employed, exceedingly little gas is evolved; during eight hours, but 1.2 cubic inches only having accumulated. This experiment was allowed to proceed overnight, and at the end of twenty-one hours, 7.0 cubic inches had been evolved. Another reading was taken at the end of the twenty-second hour, and showed that 0.8 cubic inches had been evolved during the hour. It would seem that the diastatic action of yeast on pure starch increases somewhat after some hours; but within a limit of eight hours, which covers the time that flour is in most instances subjected to fermentation, little or no action has occurred. The greater evolution of gas after twenty-one hours may possibly be due to sugar formed by the action of *bacteria* on the starch. Very striking in connection with this is the result obtained in experiment No. 7, for when the ungelatinised starch was mixed with flour infusion and subjected to fermentation, 8.5 cubic inches of gas were obtained in eight hours. The flour infusion must under these circumstances have succeeded in hydrolysing some of the starch; for although starch is washed most carefully, there will always be a certain number of cells whose walls are sufficiently thin to permit diastasis to occur; and as stated in a previous chapter, some investigators are of opinion that even unbroken wheat starch cells are comparatively readily attacked by hydrolysing agents. (Refer to Chapter VIII., paragraph 258.) Summing up the results obtained in these experiments, it is found that—

Filtered flour infusion supports fermentation slowly.

The frequently washed residue of flour supports fermentation at about the same rate.

The entire flour, mixed with water, evolves about six times as much gas as either the filtered infusion or the washed residue from the same weight.

Kneaded and washed gluten evolves practically no gas.

Flour infusion and gelatinised starch together evolve gas in considerable quantity.

The quantity of gas is increased when the infusion and the gelatinised starch remain together some time before fermentation; which result is due to diastasis by the proteins of the infusion.

Ungelatinised starch, under the influence of yeast and flour infusion, evolves a moderately large quantity of gas.

Gelatinised starch alone undergoes little or no fermentation during a period of eight hours, but ferments slowly after standing some twenty hours.

370. Further Investigation of Fermentation of Flour Infusion.—In order to further determine the source of gas during the fermentation of flour infusion, the following experiments were made:—A forty per cent. filtered infusion of stone milled flour, from English wheat, was prepared by taking 600 grams of flour, and 1500 c.c. of distilled water: these were several times shaken together during half an hour, and then allowed to subside. The upper layer of liquid was next poured off and filtered through washed calico: this was subsequently again filtered in the ordinary manner through paper until perfectly clear. On testing with iodine no colour was produced, thus showing the absence of both starch and amyloïns. The specific gravity of the infusion was 1008.5, being somewhat higher than that of the forty per cent. infusion used in a previous experiment. A portion of the infusion was tested for sugar, before and after inversion, and also for proteins. Six ounces of the infusion were then fermented at 25° C., with a quarter-ounce of compressed yeast. The experiment was continued for twenty-two hours, at the end of which time fermentation had entirely ceased. The clear liquid was then decanted off from the layer of yeast at the bottom, and tested for sugar and proteins as was done in the separate portion of the original infusion. To the yeast remaining in the bottle there was at once added a half-ounce of sugar and six ounces of water at 25° C., and the testing apparatus set up, and the quantity of gas evolved measured.

The sugar was estimated by Fehling's process in the following manner:—A weighed quantity of the flour infusion was raised to the boiling point, and maintained at that temperature for about five minutes, in order to coagulate proteins; the loss by evaporation was then made up by the addition of distilled water, and the solution filtered.

Quantities taken = 25 c.c. Fehling's Solution.
50 c.c. Water.
20 c.c. Forty per cent. Flour Infusion.

Weight of cuprous oxide, Cu_2O, yielded = 0.1531 gram. Assuming this precipitate to be due to maltose, then

$0.1531 \times 0.7758 = 0.1187$ gram of maltose in 20 c.c. of the flour infusion = 1.48 per cent. of maltose in the flour.

In the next place, 50 c.c. of the flour infusion were taken, 5 c.c. of fuming hydrochloric acid added, and the solution inverted by being raised to 68° C. The acid was then neutralised by solid sodium carbonate, and the solution made up to 100 c.c. with water. This produced a twenty per cent. inverted solution.

Quantities taken = 25 c.c. Fehling's Solution.
50 c.c. Water.
20 c.c. Twenty per cent. inverted Flour Infusion.

Weight of cuprous oxide, Cu_2O, yielded = 0.1860 gram.

In 20 c.c. of a forty per cent. solution there would be double this quantity = $0.1860 \times 2 = 0.3720$ gram. From this must be deducted the amount of precipitate due to the maltose present.

$0.3720 - 0.1531 = 0.2189$ gram of Cu_2O due to a reducing sugar produced by inversion. Assuming this sugar to be cane-sugar, or at least to have the same reducing power, then

$0.2189 \times 0.4791 = 0.1048$ gram of cane-sugar in 20 c.c. of the forty per cent. infusion = 1.31 per cent. of cane-sugar in the flour.

The total sugar in the flour would thus be 2.79 per cent.

After fermentation, the upper liquid from the yeast bottle was also tested for sugars, after filtration and coagulation of proteins as before. The uninverted solution gave no precipitate whatever with Fehling's solution. A portion was next inverted with acid in the manner already described; 20 c.c. of this solution gave a slight trace of precipitate with Fehling's solution, which was too little to weigh. So far, the practical result may be summed up in the statement that **filtered aqueous flour infusion contains two or more varieties of sugar; these during the act of fermentation entirely disappear.**

The infusion was tested for proteins by distillation with alkaline permanganate solution, with the following results, calculated to the percentage present in the flour—

In the infusion before fermentation—0.76 per cent.
„ „ after „ 0.78 „

Compared with analyses of other flours, these quantities are low; this is probably accounted for by a forty per cent. infusion being made, whereas a ten per cent. infusion is used in most analyses; the more dilute solution extracts the somewhat viscous proteins with greater readiness. The only deduction from these determinations is, that the **amount of proteins in a filtered flour infusion is practically unchanged by the act of fermentation, there being no disappearance whatever of these bodies.**

The following are the results of the fermentation experiments—

No. 1. Flour Infusion, 6 oz.; compressed Yeast, ¼ oz.; Temperature, 25° C.

No. 2. Yeast from previous experiment after cessation of fermentation: Sugar, ½ oz.; Water, 6 oz., at 25° C.

At the expiration of six hours, the following quantities of gas had been evolved:—

No. 1 .. 9.6 cubic inches. | No. 2 .. 73.5 cubic inches.

As six ounces of the forty per cent. flour infusion would contain the soluble matter of 68 grams of flour, it follows that there would be present, according to the analysis, 1.89 grams of sugar. This quantity, if entirely converted during fermentation into carbon dioxide and alcohol, would yield about 32 cubic inches of gas at 20° C. By the method adopted for testing, 15 cubic inches were registered at the end of twenty-two hours; to this would have to be added a correction for the amount lost by absorption by the water, in order to obtain a correct estimate. It is difficult, when the total quantity of gas evolved is small, to determine with accuracy the loss by absorption, because the gas in the apparatus consists of a mixture in which air is predominant, consequently the rate of absorption is less than with pure carbon dioxide gas. If it were desired to accurately estimate the quantity of gas, collection over mercury would have to be adopted. This is of little importance in the present experiment, because the total measured comes well within the amount of gas that the sugar would theoretically yield. In other words, there is no need to go outside the sugar to find a source from which the carbon dioxide is obtained, as the whole of the sugar disappears, and in the act of fermentation is capable of yielding more gas than that observed to be evolved. That the cessation of fermentation is not due to the exhaustion of the yeast is proved by experiment No. 2, in which the same yeast has more sugar added to it, when a vigorous fermentation was immediately set up. That the cessation of fermentation is due to the exhaustion of the sugar is proved by that compound being absent on analysis of the infusion after fermentation. Summing up the whole of the results—

FLOUR INFUSION.

Before Fermentation.	*After Fermentation.*
Sugar, 1.89 grams in the six ounces of infusion.	Sugar, absent.
Proteins, 0.517 gram present.	Proteins, 0.530 gram present.
	When Fermentation had ceased, 15 cubic inches of gas had been evolved, and the yeast was still unexhausted, and capable of inducing fermentation in fresh sugar solution.

Reasoning on these results, together with those obtained in the series of experiments on flour and its various constituents taken separately, the only logical conclusion is that the fermentation of dough is essentially a saccharine fermentation.

It may be demurred that the circumstances are different in an aqueous infusion to those which hold in a tough elastic mass such as dough. But it is inconceivable that the fermentation actually immediately depends on the conversion of any but soluble constituents of the flour into gas; therefore, if those proteins, so soluble as to pass through filter paper, are not capable of yielding gas as a result of fermentation by yeast, it follows that the more insoluble protein compounds likewise will not yield gas. The fact that washed gluten yields no gas affords corroborative proof of this point. (The small quantity actually obtained by experiment may be accounted for by the well-known difficulty of perfectly freeing gluten from all starchy and soluble matters.) That the fermentation of the flour itself yields several times more gas than does the filtered infusion, lends no support to the theory that it is the protein matter that is evolving gas, because it has been shown that pure ungelatinised starch causes a marked evolution of gas, being doubtless first converted into dextrin and maltose by diastasis. The fermentability of the washed residue is also accounted for by its containing starch. Supposing even that in dough, after fermentation had ceased, sugar as such existed and could be removed and detected by analytic methods, that of itself would be no proof of the evolution of gas being at the expense of the proteins, or peptones derived therefrom (for the argument equally applies to these latter bodies), because simultaneously with the fermentation produced by the yeast there is a production of sugar by diastasis of the starch. Fermentation of sugar in a stiff dough is rough work for yeast cells, and it may well be that after a few hours they are thoroughly exhausted, and disappear through disruption of their cell walls: the continuance of diastasis would still cause the slow production of more or less sugar. Further, the diastasis of the starch must throughout fermentation *precede* its subsequent conversion into carbon dioxide and alcohol; and so, if the reaction be stopped at any point, more or less sugar would as a rule be found. Again drawing a conclusion, **the fermentation of dough is in part due to the fermentation of the sugar present, in part to the diastasis of a portion of the starch of the flour and its subsequent fermentation; these sources are sufficient, and more than sufficient, for the production of all the gas evolved; these statements admit of experimental proof. There is no satisfactory evidence in favour of the gas evolved being in any sensible degree derived from the protein constituents of dough.** It should be noticed that no assertion is made that no gas whatever is derived from the protein constituents of flour; it is possible that in extreme cases gas is produced from protein matters as a result of butyric and putrefactive fermentations; but in ordinary bread-making, as it holds in America and the United Kingdom, the amount of gas derived from this source is of no importance compared with that from sugar, and indirectly from starch. Whatever amount of gas there is that is thus obtained from proteins is the result, not of the action of yeast, but of *bacteria*. Further, the statement that protein bodies do not themselves evolve gas during panary fermentation must not be construed into meaning that they do not affect the quantity evolved. In their capacity as nitrogenous yeast-foods, they aid the yeast in its development, and consequently in its production of gas by decomposition of saccharine bodies.

371. Effect of Salt on the Fermentation of Flour.—Most bakers are familiar with the general statement that salt retards fermentation: in order to determine the amount of such retardation the following experiments were made. In the first, flour and water alone were fermented; the others consisted of flour mixed with salt solutions of various strengths. The appended table contains the results:—

Date, May 27, 1885.

No. 1. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 2. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.; salt, 2.5 grams = 1.4 per cent. salt solution.

No. 3. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.; salt, 5.0 grams = 2.9 per cent. salt solution.

No. 4. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.; salt, 8.5 grams = 5.0 per cent. salt solution.

At the termination of six hours, the following quantities of gas had been evolved:—

No. 1 ..	18.2 cubic inches.	No. 3 ..	15.1 cubic inches.
No. 2 ..	15.2 ,,	No. 4 ..	13.3 ,,

In the first test, 19.2 cubic inches of gas were evolved in seven hours, while with 1.4 per cent. of salt present in the solution (No. 2) the gas was diminished to 15.8 cubic inches. Summing up the conclusions derived from this series of experiments—

The use of a 1.4 per cent. solution of salt instead of water produced a marked diminution in the evolution of gas.

Increasing the amount of salt to 2.9 per cent. made very little difference on the speed of fermentation.

With 5.0 per cent. of salt, gas was evolved still more slowly.

372. Effect on the Fermentation of Sugar of the addition of Flour and Potatoes.—In order to throw light on this point, the experiments recorded in the following table were performed.

Date, May 21, 1885.

No. 1. Sugar, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; raw flour, 5 grams.

No. 2. Sugar, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; flour, 5 grams, gelatinised in small quantity of water and allowed to cool.

Date, May 18, 1885.

No. 3. Sugar, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; potato, 5 grams, boiled.

No. 4. Sugar, ½ oz.; compressed yeast, ¼ oz.; potato, 5 grams, in small pieces, boiled; clear filtered water employed for boiling them, made up to 6 oz. at 30° C., and used instead of ordinary water.

Quantities of gas evolved in six hours:—

No. 1 ..	84.3 cubic inches.	No. 3 ..	138.1 cubic inches.
No. 2 ..	135.0 ,,	No. 4 ..	133.6 ,,

In the first experiment, with raw flour, the quantity of gas evolved keeps very close to that evolved from the sugar solution and yeast only, until three hours have elapsed. After that time the speed of evolution of gas falls off sharply, until in nine hours the quantity of gas evolved is only just as much as the sugar alone had evolved in six hours. The actual diminution of speed of the evolution of gas, as a result of the presence of flour, is noticeable in several experiments. With gelatinised flour, on the other hand, the fermentation proceeds more rapidly, and to a greater extent than with sugar only. The result of No. 3 with boiled potato is almost similar to No. 2. No. 4, containing boiled potato water, ferments at almost exactly the same rate as did No. 3 with the whole of the potato. Summing up,

The addition to sugar of—

Raw flour retarded the fermentation in the latter part of the experiment.

Gelatinised flour, boiled potato, and boiled potato water, each stimulated and increased the amount of fermentation to about the same degree.

373. Effect of Temperature on Fermentation.—In order to measure quantitatively the effect of variations of temperature on the production of gas by fermentation, the following experiments were made:—Two different brands of compressed yeast were employed, one of which is designated yeast "A," the other yeast "B"; the same quantity of yeast was employed throughout the experiment. The series included tests by each yeast on sugar, yeast mixture and flour, at the respective temperatures of 20°, 25°, 30°, and 35° C. = (68°, 77°, 86°, and 95° F.).

The following are the results of one set of tests:—

Date, July 3, 1885.—The complete series at 20° C. made this day.
„ July 2, 1885.— „ „ 25° C. „
„ June 30, 1885.— „ „ 30° C. „
„ June 29, 1885.— „ „ 35° C. „

No. 1. Yeast mixture, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 20° C.
No. 2. Yeast mixture, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 25° C.
No. 3. Yeast mixture, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 30° C.
No. 4. Yeast mixture, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 35° C.

Gas evolved at the end of six hours:—

No. 1	83.8 cubic inches.	No. 3	177.8 cubic inches.
No. 2	113.3 „	No. 4	175.0 „

(At the end of three hours, Nos. 3 and 4 had evolved 104.2 and 128.0 cubic inches respectively.)

Considering first the series consisting of yeast A with yeast mixture, a temperature of 25° C. increases the total quantity of gas considerably over that evolved at 20° C.; a further increase to 30° more than doubles the average speed of evolution of gas. Beyond 30° the amount of gas evolved is not materially increased with the rise in temperature, thus at 35° C. there is very little more gas evolved than at 30° C. In the series where sugar is substituted for yeast mixture, the production of gas is less, but the same general relation exists between the various members of the series.

With flour, on the other hand, there is a more equal increase, as shown by the following table, still there is a greater increase between Nos. 2 and 3 than the others:—

No. 1. Flour, 34 grams; compressed yeast, A, ¼ oz.; water, 6 oz. at 20° C.
No. 2. Flour, 34 grams; compressed yeast, A, ¼ oz.; water, 6 oz. at 25° C.

No. 3. Flour, 34 grams; compressed yeast, A, ¼ oz.; water, 6 oz. at 30° C.
No. 4. Flour, 34 grams; compressed yeast, A, ¼ oz.; water, 6 oz. at 35° C.

Gas evolved at the end of six hours:—

No. 1 ..	14.6 cubic inches.
No. 2 ..	18.2 ,,
No. 3 ..	24.4 cubic inches.
No. 4 ..	28.3 ,,

Another precisely similar series of experiments was made with B yeast, which, being the stronger yeast of the two, gave off in every case more gas than did yeast A in the corresponding experiment. This difference was not so striking when yeast mixture was used, because its stimulating effect helped the weak yeast proportionally the more. But in sugar each yeast has to depend more fully on its own vitality in producing fermentation. Consequently the stronger yeast B causes the evolution of a proportionately higher quantity of gas than does the yeast A.

Summarising the results obtained—

In the three media employed, the rapidity of production of gas increases with the temperature; this increase is more marked between 25° and 30° than between 30° and 35° C.

374. Behaviour of Yeasts at High Temperatures.—In view of the fact that, in baking, some of the work of the yeast is done in the oven, it becomes of interest to ascertain how different yeasts behave as fermenting agents at high temperatures. For this purpose the following experiments were made in 1895:—

EXPERIMENT ON YEAST AT 77° F. (25° C.)

Quantities taken—yeast, ¼ oz.; flour, 2.4 oz.; water, 6 oz.
No. 1.—Compressed distillers' yeast.
,, 2.—Compressed brewers' yeast, ordinary.
,, 3.— ,, ,, ,, special.
,, 4.—Thin brewers' yeast.

GAS EVOLVED IN CUBIC INCHES.

Time.	No. 1.	No. 2.	No. 3.	No. 4.
1 hour	4.0	2.0	7.0	—
2 hours	—	6.0	15.0	—
3 ,, ...	15.0	10.0	18.5	4.0
4 ,, ...	—	13.0	22.5	6.5
5 ,, ...	—	—	—	8.0
5½ ,, ...	21.0	—	—	—
7 ,, ...	22.0	—	—	

Yeasts Nos. 1 and 4 were next tested in precisely the same manner, except that the temperature was raised to 122° F. (50° C.) The following were the results:—

GAS EVOLVED IN CUBIC INCHES.

Time.	No. 1.	No. 4.
1 hour	13.0	1.0
2 hours	22.75	—
2½ ,, ...	23.15	—
3 ,, ...	Stop	1.5

Notice how completely No. 4 ceases work at this higher temperature; while No. 1 for a time is even more energetic in action.

In the next place a series of tests were made at 131° F. (55° C.). The quantities taken were not precisely the same as in the previous tests, but are given in detail.

No. 1. Compressed distillers' yeast, ¼ oz.; flour, 1.2 oz.; water, 6 oz.
No. 1*a*. Yeast as No. 1; sugar, ¼ oz.; water, 6 oz.
[No. 4. Thin brewers' yeast did not work with flour at 122° F.]
No. 4*a*. Thin brewers' yeast, ¼ oz.; sugar, ¼ oz.; water, 6 oz.
No. 5. Another sample compressed distillers' yeast, ¼ oz.; flour, 1.2 oz.; water, 6 oz.
No. 5*a*. Yeast as No. 5; sugar, ¼ oz.; water, 6 oz.

Gas Evolved in Cubic Inches.

Time.	No. 1.	No. 1a.	No. 4a.	No. 5.	No. 5a.
15 minutes ..	1.0	1.25	—	2.0	2.0
30 „ ..	4.0	5.0	—	2.75	3.0
1 hour	6.25	7.75	2.75	3.0	3.5
2 hours	6.5	8.75	4.0	3.5	5.5
3 „	7.0	10.0	5.75	—	—
4 „	Stop	10.75	Stop	4.0	7.5

Comparing the two samples of distillers' yeast; No. 1, it will be noticed, works more vigorously, both in flour and in sugar, than No. 5. The thin brewers' yeast, No. 4, works at this temperature in sugar; although inactive in flour and water, at a temperature lower by nine degrees. At a temperature of 140° F., neither Nos. 1 nor 4 evolved any gas in a sugar solution. These results agree broadly with the general behaviour of the yeasts during baking. They were first published by one of the authors in *The Science and Art of Bread-making*, 1895, and establish the fact that at high temperatures, distillers' yeast retains its activity to a much higher point than does English brewers' yeast.

375. Comparative Fermentative Tests with Brewers' and Distillers' Yeasts in Flour and Sugar Solutions.—The following experiments were made with the view of comparing the fermentative capacity of brewers' and distillers' yeasts in flour and sugar solutions respectively:—

No. 1. Sugar, ½ oz.; water, 6 oz. at 25° C.; distillers' compressed yeast, ¼ oz.
No. 2. Flour, 68 grams; water, 6 oz. at 25° C.; distillers' compressed yeast, ¼ oz.
No. 3. Sugar, ½ oz.; water, 6 oz. at 25° C.; compressed English brewers' yeast, ¼ oz.
No. 4. Flour, 68 grams; water, 6 oz. at 25° C.; compressed English brewers' yeast, ¼ oz.

The following were the quantities of gas evolved in six hours:—

No. 1 ..	40.8 cubic inches.	No. 3 ..	80.0 cubic inches.
No. 2 ..	32.3 „	No. 4 ..	1.9 „

No. 1 calls for no special remark, being similar in character to many tests previously made. The quantity of flour in No. 2 is double that used in previous experiments, the object being to get a mixture which should be a nearer assimilation to dough, while still possessing sufficient fluidity to permit the escape of the produced gas. As might be expected, the amount of gas evolved is higher than in tests where 34 grams were used. No. 3 was a test with the compressed brewers' yeast—there is a more rapid evolution of gas than in the corresponding test with the distillers' yeast; so far, the verdict would be in favour of the brewers' yeast as being a stronger yeast. This verdict is borne out by the results of commercial use of the yeast for brewing purposes. Next comes test No. 4, the results of which are most remarkable; the English brewers' yeast, which had been by far the stronger in sugar solution, causes practically no evolution of gas whatever from the flour mixture. On the next day the experiments were repeated, with similar results.

376. Brewers' Yeast and Ferments.—When brewers' yeast is employed for bread-making purposes it is usual first to allow the yeast to develop in a "ferment," generally composed of boiled potatoes rubbed down through a sieve into water, and a little raw flour added. In order to ascertain the effect of different substances as constituents of a "ferment," the following experiments were made:—

		Water.	Brewers' Yeast.
No. 1.	Sugar, 1 gram	200 c.c.	2 grams.
No. 2.	Boiled potatoes, 5 grams	„	„
No. 3.	Filtered potato juice, 10 grams ..	„	„
No. 4.	Malt extract, 2.5 grams	„	„
No. 5.	Diastatic malt extract, 2.5 grams	„	„
No. 6.	„ „ „ killed, 2.5 grams	„	„

No. 6 was precisely similar to No. 5, except that the solution had been raised to the boiling point, with the view of destroying the diastase present.

The following were the quantities of gas evolved after six and a half hours' fermentation at 30° C.:—

No. 1 ..	125 cubic centimetres.	No. 4 ..	160 cubic centimetres.
No. 2 ..	25 „	No. 5 ..	76 „
No. 3 ..	16 „	No. 6 ..	74 „

After fermentation had ceased, and about twenty hours from the commencement of the experiment, 50 grams of flour were added to each "ferment," and the bottle again immersed in the bath at 30° C., and readings taken of the quantities of gas evolved. At the end of six hours, these were:—

No. 1 ..	23 cubic centimetres.	No. 4 ..	43 cubic centimetres.
No. 2 ..	11 „	No. 5 ..	15 „
No. 3 ..	31 „	No. 6 ..	30 „

As a ferment constituent potato juice causes the evolution of less gas than do potatoes, while as a stimulant on the yeast's after-power of inducing fermentation in flour the juice is far the more efficacious. While the gas evolved in the two diastatic malt extract solutions is practically the same, that in which the diastase had been destroyed acted in this case as the more energetic after-stimulant of flour fermentation. Possibly a concentrated solution of diastase may exert some retarding influence on the energy of yeast. In an experiment conducted in this fashion the action of the yeast in the mixture of flour and water is less in all cases, except No. 4, than when the yeast and flour mixture are fermented direct (36 cubic centimetres). During the working of the "ferment," the operation was carried on without access of air, a condition which may have had a retarding action on the energy of the yeast (*Science and Art of Bread-making,* Jago, 1895, p. 223, *et seq.*).

377. Toxicity of Flour to Yeast.—In view of recent investigations on the toxic behaviour of flour towards yeast, the experiments described serve to show that flour retards the fermentative action on sugar of brewers' yeast. (Distillers' yeast is also similarly affected, but only to a much less extent.) In this relation it is interesting to note the work that has been done on what are called "toxalbumins." In investigations carried out on the proteins of the seed of *Ricinus,* it has been shown that its toxic property belongs to the protein, and is closely related to the proportion of coagulable albumin contained in various fractions of the seed protein. It seems, therefore, almost certain that true toxalbumins occur in seeds (*The Vegetable Proteins*, Osborne, 1909, p. 96). Michaelis has also pointed out that foreign protein matter is under all circumstances a deadly poison for yeast, and that this is rendered innocuous by the proteolytic enzyme present. It is probably therefore the protein of flour which exerts a retarding action on fermentation.

Baker and Hulton have recently (1909, 1910) reinvestigated this matter, and have confirmed the just quoted conclusions of one of the authors, viz., that the presence of flour inhibits the fermentation of a solution of sugar by brewers' yeast. Independently, Lange, in the course of a series of investigations, conducted in 1904 and 1905, re-discovered that the flour of wheat and certain other grains exercised a poisonous action on yeast, and especially brewers' types of yeast. The following is a synopsis of the work and conclusions of Lange, Henneberg, Hayduck, Wendel, Baker, and Hulton on this and closely allied subjects. The authors are indebted to the *Treatise on Brewing* by Sykes and Ling for a résumé of a lecture by Delbrück before the London section of the Institute of Brewing in 1906, from which many of the conclusions of the above named German authorities are gleaned. The lecture is reported more fully in *Journ. Inst. Brewing*, 1906, 642. From Hayduck's researches, the lecturer, Delbrück, derived the laws that in the production of yeast, the fermenting power is in inverse ratio to the multiplication of the yeast-cells. Moderate multiplication produced a yeast rich in protein; a rapid multiplication, on the other hand, produced a yeast poor in protein. Therefore everything which hindered multiplication, such as a low temperature, the shutting off of air, lack of movement, fermentation under carbon dioxide pressure, conduced to the yielding of a yeast which was rich in protein and in fermenting power. Obviously, therefore, these are among the matters to be considered in the manufacture of a vigorous yeast. It is also evident that such treatment must not be carried to extremes, since an undue restriction of multiplication would seriously lessen the output of yeast. In yeast manufacture the conditions must be so balanced as to obtain the maximum of vigour combined with a fair production of yeast.

Delbrück also dealt with an inquiry which is so frequently made, what important physiological significance has the peculiar dynamic effect of the splitting up of sugar into alcohol and carbon dioxide? To this he replies that it is easy to say that a sort of subtle respiration process was going on here—that the cleavage was a hidden source of heat; but the significance of this activity was, particularly from a zymo-technological point of view, far more comprehensive. It was known that the most powerful defensive agencies of the yeast against the attacks of foreign organisms lay in its fermentation energy. Delbrück had always looked upon the fermentative effect of the yeast in this light, and had demonstrated that its organism, in sending out carbon dioxide and alcohol, thus protected itself against all the organisms for which these substances were poisonous. The effect of the carbon dioxide is ten times as deadly as that of the alcohol. Delbrück therefore arrives at the conclusion that zymase (the yeast enzyme which decomposes sugar into alcohol and carbon dioxide) is not only a respiration enzyme, but also a fighting enzyme. He also regards the proteolytic enzyme of yeast, as a part of its fighting organisation, inasmuch as it attacks all inimical organisms, dissolving and killing them. As already mentioned, foreign protein matter is a poison to yeast, and this is rendered innocuous by the action of the proteolytic enzyme by which it is degraded. The law that in the struggle for existence, those organisms which specialised in the production of fighting substances and in the cultivation of fighting enzymes, would be the strongest, applies especially to the micro-organisms. Lactic acid bacteria possessed means of defence in the lactic acid enzyme, while the butyric acid bacteria were similarly protected by the production of butyric acid, a substance which is pernicious in its effects on other organisms. It was in the course of these researches that Lange independently re-discovered that bruised grain (or bran) or meal, or even an aqueous extract of them, had a poisonous effect on yeast. He further found that different kinds of yeast varied in susceptibility to this poisonous action. Thus the distillers' yeast races were capable of offering resistance, but such power was less marked in brewers' top-fermentation yeast, and still less so in the bottom-fermentation type of brewers' yeast. As to the nature of these poisonous substances, there was some probability that they belonged to the proteins and to the enzymes produced by them, since the injurious action could be neutralised by heating the grain or its aqueous extract. The following are some of the more important conclusions of the German authorities. The toxic action only becomes manifest when the yeast and cereals are present together in *distilled* water. Rye, wheat, and barley, in the form of grits or flour, placed with bottom-fermentation beer-yeast in a solution of saccharose, will kill up to 99 per cent. of the yeast in a few minutes. Maize and oats do not show this toxic action. By agitation with distilled water, the flours of rye and wheat furnish extracts that are also toxic toward beer-yeast, but to a far less extent than the corresponding solid substances. The protein sludge separating from the coarser particles when rye grits are shaken up with water is specially poisonous. The same effect is produced by the glutinous mass obtained by kneading wheaten flour under water. It is probable that the toxic substance must be sought among the proteins, or may be produced therefrom by the action of the yeast. All these toxic effects are completely obviated by the addition of a small quantity of inorganic salts to the solution, lime salts being the most effective, and next to them magnesia salts. A partial or complete removal of the toxic action can be effected even by replacing distilled water by tap-water. Among other substances exerting a strongly poisonous action on low-fermentation beer-yeast is egg-albumin. Wheaten flour seems also to exert a toxic action on high-fermentation distillers' yeast, but this requires confirmation (*Treatise on Brewing,* Sykes and Ling).

These conclusions, it will be noticed, apply to bottom-fermentation beer-yeast, whereas in the experiments previously described as having been made by one of the authors top-fermentation beer-yeast was employed. This, though admittedly less susceptible to the inhibitory action of the active cereals, is nevertheless similarly affected. Further, in these experiments, no definite retarding action was caused by the addition of egg-albumin. It is possible that the low temperature evaporation of this body to dryness in the preparation of the desiccated product may have modified its inhibitive action.

378. Baker and Hulton's Researches.—In 1909, these writers communicated to the Society of Chemical Industry the results of some researches on the action of wheaten flour on brewers' yeast. This was followed by a paper on the "Toxins in Cereals," which appeared in the *Journal of the Institute of Brewing* in 1910. The experimental work confirms that previously described, and among other things goes to show that with mixtures of flour and water, tap-water enables a greater amount of gas to be evolved than does distilled water. Thus with 20 grams of Hungarian flour, 50 c.c. of water, and 1 gram of unwashed pressed brewers' yeast, fermented at 110° F., the following results were obtained at the end of four hours:—

	Carbon Dioxide Evolved.
Brewers' Yeast and Distilled Water	10 c.c.
Distillers' ” ” ”	287 ”
Brewers' Yeast and Tap-water	35 ”
Distillers' ” ” ”	287 ”

The tap-water contained in grains per gallon:—

Total Solids	21.42
Solids after ignition	19.74
Silica	0.28
Lime	7.60
Magnesia	0.71
Sulphuric Acid (SO_3)	2.69
Potash	0.42
Soda	1.26
Chlorine	1.40
Nitric Acid (N_2O_5)	0.31

Using the tap-water it will be noticed that the activity of the brewers' yeast is much increased. On examination of the results caused by the addition of various inorganic salts to tap-water, it was found that potassium sulphate, calcium chloride, sodium chloride, and many other salts act as accelerants. Baker and Hulton regard potassium sulphate as the most favourable of these, and find that a solution containing 0.6 gram per 100 c.c. exerts a very decided accelerating action. They make the following suggestion as to the reason of the difference between the two yeasts (distillers' and brewers')—

In a distillery wash, before the yeast is introduced, there are present large quantities of raw cereals, such as barley and rye, containing toxins, and since the distiller pitches his yeast into unboiled wort and therefore one with this cereal poison still active, only those yeast cells which can survive and are immune to such toxic substances and can reproduce in this environment will carry on the race, giving rise to cells inheriting this advantageous variation. There will thus be obtained in a few generations by natural selection what is to all intents a new species bearing this character of immunity to cereal poison. When such yeast is used for breadmaking, where it is again exposed to the action of the toxic substance in wheaten flour, the high gas yield at once shows that it is now immune, while brewers' yeast which has always been grown in a boiled, and therefore non-poisonous wort, is readily susceptible. The accelerating influence of potassium sulphate, sodium chloride, etc., on the fermentation of flour with brewers' yeast is thus seen to be correlated with the protective function these salts exert on the yeast by negativing the toxic effect of the flour, while distillery yeast which is already immune to these toxins, from having been grown in their presence, needs no such protection, and is, in fact, not activated by these salts (*Journ. Inst. Chem.*, July, 1909).

Baker and Hulton do not attribute the protective action of potassium sulphate to any "salting out" of proteins, but conceive that it may lie in some kind of physiological stimulation of the yeast, whereby it is rendered more resistant to an unsuitable environment. They further point out that brewers' yeast, which was formerly used for bread-making, is now practically useless, the reason being possibly due to the fact that modern flours being better milled contain a smaller proportion of fibre, husk, etc., than formerly. The husk probably has a protective action towards brewers' yeast similar to that of salts ("Toxins in Cereals," *Journ. Inst. Brewing,* xvi, April, 1910).

In making this suggestion the writers have apparently overlooked the fact that when brewers' yeast was so largely employed for bread-making, it was the custom to use a ferment consisting of boiled potatoes with their skins on, the water in which they were boiled, and raw flour. The yeast was allowed to work and multiply in this mixture before being introduced into the sponge (earlier dough stage). The stimulating effect of potatoes as an agent in fermentation has been already described in paragraph 372.

EXPERIMENTAL WORK.

379. The student who has the opportunity will do well to perform for himself most of the experiments described in this chapter, and compare the results he obtains with those here recorded. He should commence by making duplicate tests with the same yeasts, in order to gain the requisite accuracy and practice in working. The experiments described in the 365th and following paragraphs, or as many of them as practicable, should be performed. It is recommended that 25° C. be adopted as the standard temperature throughout the experiments, instead of 30° C. Practical directions follow.

380. Apparatus requisite.—Water-bath to hold yeast bottles, sets of yeast testing apparatus, pneumatic troughs, bunsen burner and automatic temperature regulator, thermometer, etc.

The water-bath may conveniently consist of a large iron saucepan (or Scotch "goblet"); to this should be attached a side-tube, by means of which the height of the water in the bath may be regulated: for description of this very useful device see "The Hot-Water Oven," Chapter XXI. Adjust the height of the water in the bath, so that the yeast bottles, when charged, shall be on the verge of floating, the surface of the liquid in the bottle will then be about an inch below that of the water in the bath. During very hot weather, and particularly when working at the lower temperatures, it is advisable to have a stream of cold water running through the bath. For this purpose, lead the end of a piece of bent tube, connected with a water tap, into the bath over the top, on the opposite side to side-tube before referred to: turn on a small stream of water through this bent tube, scarcely more than what would cause rapid dropping from its end. Water will then be continually finding its way in through this tube, and making its exit through the side-tube: thus lowering the temperature when necessary. Do not let the stream from this cold water tube impinge directly on either of the yeast bottles.

The construction and arrangement of the yeast testing apparatus and pneumatic troughs have already been sufficiently fully described.

381. Automatic Temperature Regulator.—The bath is warmed by means of a bunsen burner arranged underneath, and, in order to maintain the temperature at any desired point, an automatic regulator is employed. As an unvarying temperature is necessary for several other chemical operations, a detailed description of such an automatic regulator is given. There are several of these instruments made and sold under various names; but for general purposes the following modification, designed by one of the authors, and shown in Fig. 22, is simple and not likely to get out of order. An improved form of this instrument is now made by Baird and Tatlock Ltd., of London.

The instrument consists of a bulb, *a*, about 4 inches long, and ¾ inch in diameter; to this is attached a stem, *b b*, about a ¼ inch diameter, and 6 inches long. This stem bends over at the top, and is connected with a U-tube, *c d e*, ¼ inch diameter, in which are blown 2 bulbs as figured, *f f*, about ¾ inch diameter. The one end, *c*, of this U-tube is closed with a stopper, *g*, which is ground in with extreme accuracy. From the centre of the bottom of this stopper, a hole is bored upwards for a short distance, which hole joins another bored inwards through the side of the stopper; this hole, therefore, affords a passage up through the bottom of the stopper and out through its side. A corresponding hole is bored through the side of the neck, *c*, of the U-tube, so that if the stopper be turned so that these two holes coincide, a passage is provided from the U-tube to the exterior; this exit may be closed at will by slightly turning this stopper, *g*. To the other end, *e*, of the U-tube, *c d e*, is sealed a bent tube, *h i j*; below the point, *e*, this tube, *h i j*, is made much finer, having its smaller end, *j*, 3/32 inch in diameter, and ground obliquely as shown in the figure. Below the joint, *e*, but as near to it as possible, an outlet tube, *k l*, is sealed into the U-tube, *c d e*. This completes the regulator; the method of using the instrument, and its principle, may be conveniently described together.

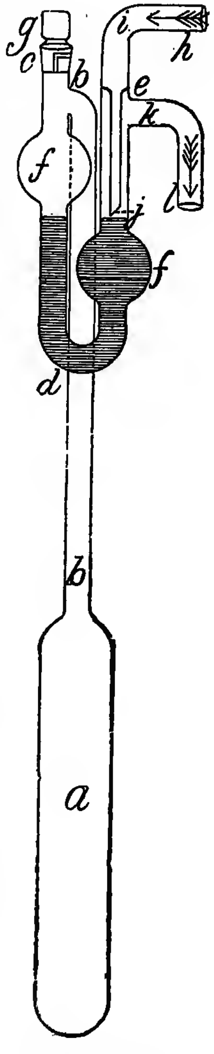


Fig. 22.—Automatic Temperature Regulator.

By means of a screw-clamp carried on a retort-stand, or any other suitable holder, fix the regulator upright, and so that the bulb, *a*, shall be wholly immersed in the water of the bath, and the ends of the tubes, *h* and *l*, projecting over its side. The regulator should be perfectly rigid when fixed; the clamp is best screwed on to the stem, *b b*. Connect up *h* by india-rubber tubing with the gas tap, and join up *l* to the bunsen burner. Partly fill the U-tube, *c d e*, with carefully cleaned mercury through *c*. Turn on the gas and light the bunsen burner, then continue the filling of *c d e* with mercury until the level rises sufficiently high in the limb, *d e*, to very nearly close the end of jet *j*. The quantity of mercury added should be sufficient to just begin to shut off the supply of gas to the bunsen; it is evident that then a very slight rise in level of the mercury would either considerably diminish or entirely shut off the gas from the burner. Next heat a little india-rubber sufficiently to liquefy it; smear the stopper, *g*, and its neck with this liquid, taking care to preserve a clear passage through the hole in the stopper. Then pour some of the strongest alcohol obtainable, which has been recently boiled, through *c*, until the bulb, *a*, its stem, *b b*, and the part of *c* are completely filled with alcohol. Insert the stopper, *g*, so that the hole through it is open; the excess of spirit escapes. It sometimes happens, in filling the instrument with spirits, that the level of the mercury in the U-tube is disturbed, the spirits floating on its surface at *c*, forcing up the level in *e* sufficiently far to entirely close the jet, *j*. Should this happen, the mercury must again be adjusted by removing a small drop by means of a fine pipette. Having made these adjustments, the instrument may be regulated for any desired temperature. Place a thermometer in the bath, so that the height of the mercury can be easily read and that its bulb does not touch the bottom. Suppose it is wished to maintain the bath at 25° C., turn the stopper, *g*, so that the hole is open, and light up the burner. The gas finds its way through the tubes, *h i j k l*, in the directions of the arrows. As the temperature of the water in the bath increases, so does that of the spirits in *a*. With a rise in temperature the alcohol expands, and a small portion finds its way out through the hole in the stopper, *g*. Watch the thermometer carefully, and when the temperature stands at about one-tenth of a degree below 25° C., turn the stopper, *g*, so as to close the hole through it. The spirit, in expanding, now finds no means of escape, and therefore drives down the mercury in *c d*, causing a corresponding rise in *d e*; the consequence is that the jet, *j*, is either wholly or partly closed, and the gas either completely or partly shut off from the burner. The bunsen used should have a cap of fine wire gauze fastened on to it, so as to prevent its lighting at the bottom when the flame is turned very low. A small pin-hole burner should be fixed to the bunsen, and fed from an independent supply, so as to re-light it should the regulator turn it completely out; this "pilot" burner must be turned down so as to only give a flame about ¼ inch high, and should not be able to appreciably warm the bath. The regulator will at first most likely shut off the gas completely; the bath will then cool slightly, and as the alcohol in *a* contracts, the level of the mercury in *d e* will fall, and so the jet, *j*, will once more be opened, and a passage of gas to the burner permitted. With this regulator properly set, the temperature keeps between two extremes that after a short time closely approach each other; in fact, the mercury so adjusts itself as to partly close the aperture *j*, allowing just sufficient gas to pass to keep the bath at a constant temperature. The end of *j* is cut obliquely in order to prevent the mercury sticking to it, and so acting irregularly. Alcohol is used in *a* instead of air, because it is not affected by changes of atmospheric pressure; when temperatures above the boiling point of alcohol are required, the instrument must be used with air, or else some liquid having a sufficiently high boiling point. Alcohol is preferable to water, because it has a much higher co-efficient of expansion, that is, for an equal rise in temperature it expands much more. With the instrument set as described, it should maintain the temperature closely at 25° C.; if it should be found to be somewhat higher, the instrument may be made more delicate by adding a very little more mercury, or it may be shut off somewhat earlier; thus, if it be found to give a constant temperature 0.4° over that at which the stopper, *g*, is shut off, then all that is necessary is to always shut off at 0.4° below any temperature that may be required. Should the temperature be too low, it may be raised slightly by carefully turning the stopper, *g*, momentarily, until the slightest drop of spirits oozes out; if the temperature is too high, the bath must be cooled down, and again regulated on the rising temperature. If the bath is required to be used for several days at the same temperature, all that is requisite is to turn off the gas when the day's work is done; as the bath cools, the mercury rises in *c d* through contraction of the alcohol; the bulbs, *f f*, are provided in order to allow of this rise without its altering the regulator. When the bath is next required, simply turn on the gas, and the regulator, without any attention, will maintain the temperature at the point for which it was adjusted. The advantage of this form of regulator is that it keeps perfectly constant for a very long time, as there are no parts to shift, or places from which leakage may occur; the stopper, *g*, smeared with melted india-rubber, is perfectly air-tight. Grease will not answer as well as the india-rubber, as it is dissolved by the alcohol.

382. Method of Testing.—To make one or more experiments proceed in the following manner:—First, carefully enter in the notebook the particulars of each experiment, and number them: place corresponding numbers on the bottles. Regulate the water-bath at the desired temperature, and place in it a flask containing sufficient water for the experiments that are to be made. Having cleaned the whole apparatus, arrange in order the generating bottles required, and weigh out and introduce into them the yeast mixture or other substance to be fermented. Next weigh the yeast, taking care that a good representative sample is obtained. With pressed yeast cut a thin slice off the middle of the slab, avoiding dry and crumbling fragments. Brewers' yeast must first be well stirred, and then weighed out in a counterpoised dish. Break up the pressed yeast carefully in a small evaporating basin, with some of the water which has been raised to the right temperature; for this purpose an india-rubber finger stall placed on the finger is useful. Pour the yeast and water into the bottle; rinse the basin with the remainder of the six ounces of water. As rapidly as possible introduce each sample of yeast, to be tested, in its respective bottle in precisely the same manner. Having introduced the yeast, yeast mixture, or other substance, and water, into the respective bottles, *gently* shake each bottle so as to thoroughly mix the ingredients; then tightly cork each bottle, and arrange the apparatus as shown in Fig. 21, given at the commencement of the chapter. Remove the glass stopper at *d*, and suck out the air from the apparatus until the water or brine rises in the jar, *f*, somewhat above the zero, then again insert the glass stopper. Pinch the india-rubber tubing on one side of *d* so as to make a slight opening, and thus permit air to enter; in this way lower the liquid in *f* until its level exactly coincides with the zero. Perform this operation as rapidly as possible with all the apparatus being used, and note the exact time in the notebook. As the fermentation proceeds, the surface of the liquid in the jars will become lower, and in this way a measure of the amount of gas yielded is obtained. At the end of every half-hour or hour from the commencement, read off the volume of gas, and enter the same in the notebook. When the jars are nearly full of gas watch them carefully, and as soon as the 100 cubic inches, or 500 c.c., mark is reached, withdraw the plug at *d*, blow into the jar for a few seconds so as to displace carbon dioxide through the bottom, and then suck out the air until the liquid again rises to the top of jar, re-insert the plug, and rapidly adjust the surface of the liquid to the zero. This operation should last only a very short time, and does not practically affect the results that are being obtained. The readings may be taken for from, say, two to six hours; or, if wished, until the action ceases. These directions apply equally to the ordinary use of the apparatus for testing the strength of yeasts. With the alternative displacement apparatus, the earlier part of the procedure is the same. The difference in the mode of collecting and measuring the evolved gas has been already sufficiently explained.

383. Preparation of Yeast Mixture.—It is essential that the substances composing this mixture be thoroughly mixed. The following is the best mode of procedure. First, dry the substances at a gentle heat (100° C.). In the laboratory this is done by placing them in a hot-water oven; then finely powder each in a mortar, and weigh out the right quantities. Then thoroughly mix the first four ingredients; afterwards add the fifth, and again mix; then add the sugar little by little, mixing between each addition. In this way an equal composition of the mixture throughout is assured. Coarse crystalline coffee sugar is almost chemically pure; failing this, the best loaf sugar may be used.

The pepsin necessary for the experiments may be obtained from the chemist.

The malt wort may be prepared by infusing coarsely ground malt with ten times its weight of water for two hours at 65° C.: it is then filtered and diluted down with water until at the right density.

In experiments with flour, the flour and part of the water should first be placed in the generating bottle, and thoroughly shaken before the addition of yeast.

The starch is gelatinised by allowing it to stand in a small beaker, with some water, for about five minutes in the hot water-bath, stirring thoroughly meanwhile.

The experiments on flour infusion, in which the sugar is determined before and after the fermentation, are very important, but had better be postponed until the student has proceeded with his studies of analysis.

In the temperature experiments the tests at the same temperature should be made on the same day, and the complete series with as little interval as possible between.

In addition to the experiments described in this chapter, many others will suggest themselves to the practical baker: these he may arrange for himself, and use the yeast apparatus as a means of measuring the evolution of gas, under any conditions that may be of interest to him. The student will do well, in addition, to perform the following series of tests.

384. Keeping Properties of Different Yeasts.—Procure samples as fresh as possible of different pressed, brewers', and patent yeasts. Test immediately after procuring them; then store in a cool cellar, and test each sample on successive days until they are capable of setting up little or no fermentation. To ensure perfect accuracy it is well to keep each sample of yeast in a weighed vessel; any loss by evaporation may then in the case of the liquid yeasts be made up each day by the addition of distilled water. The pressed yeast may be kept in a stoppered bottle, or, preferably, the portion for each estimation should be taken from the interior of the mass; as a check, moisture should then be estimated in the yeast each day.

385. Use of Testing Apparatus without Temperature Regulator.—In the foregoing descriptions given it has been directed that the yeast bottle stand in a water-bath regulated by an automatic temperature regulator. While such an arrangement is extremely useful, it is not absolutely necessary. For actual bakehouse use the following plan answers well. Select a place somewhere near the oven where the temperature is pretty constant, and, if possible, between 70° and 80° F. Arrange on a shelf, clamped to the wall, a saucepan sufficiently large to take the yeast bottles, and fix the trough for the graduated jar in position. The saucepan will have to be raised sufficiently high by means of blocking; this should be properly done at the outset, as the apparatus should remain there permanently. When about to use the apparatus, first of all fill the saucepan with water at the desired temperature F., and then make the estimation. A warm place being chosen, the water in the saucepan will not fall very much in temperature during the time necessary for carrying out the experiment. This method of using the apparatus applies more particularly to yeast testing than to the more delicate experiments described in the preceding pages.

CHAPTER XII.

MANUFACTURE OF YEASTS.

386. For baking purposes three commercial varieties of yeast are employed, namely, Brewers', Distillers' Compressed, and "Patent" yeasts. These latter may again be subdivided into malt and hop yeasts as used in England, and the Scotch flour barms. The superior quality of the distillers' compressed yeast has led to its now being used to the almost entire exclusion of the other kinds. Still there are districts where distillers' yeast cannot be obtained, and therefore bakers still have to manufacture their own "patent" yeast. Descriptions follow of how these different types of yeast are manufactured.

BREWERS' YEAST.

387. In the chapter on Fermentation an account is given of the appearance of an actively fermenting tun of brewers' wort. The brewer first treats his malt with water at a temperature of about 65° C. for about two hours, more or less; during that time the starch of the malt is converted into dextrin and maltose. The liquor is then allowed to drain from the grains, or husks of malt, and is transferred to a copper in which it is boiled with hops: the hops are removed and the wort rapidly cooled, either by being exposed to the air in shallow open coolers, or poured over a specially arranged apparatus, consisting of a series of pipes through which cold water is passing, and which is termed a refrigerator. This cooling must be done as rapidly as possible, as a temperature of about 30° C. is particularly suited to the rapid growth and development of disease ferments. On the wort being cooled to 18 or 19° C. (65° F.), about one one-hundred and fiftieth part of its weight of yeast from a previous brewing is added. Fermentation sets in, and after a time yeast rises to the surface, and is skimmed off. The first is rejected because any lactic ferments or other *bacteria* that may be present are, from their small size, floated up to the surface with the yeast on its first ascent. At the time when the fermentation is most active and vigorous, the best yeast is being produced. As fermentation slackens, cells are thrown to the surface which have been grown in a comparatively exhausted medium. Such yeast is weak, and possesses less vitality. For their own pitching purposes, the brewers reserve the middle yeast. Bakers who use brewers' yeast should be supplied with that equal in quality to what the brewer himself uses for starting fermentation. The yeast, when skimmed, should be stored in shallow vats, so as to admit of free access of atmospheric oxygen.

In some breweries the beer is allowed to finish its fermentation in large casks, arranged so that the bung-hole is very slightly on one side: the yeast slowly works out of the bung-hole and flows in a shallow stream down the outside of the cask until it reaches the bottom, when it drops in a gutter arranged to receive it. A number of these casks are usually arranged side by side, and connected together by a pipe at the bottom;

they are consequently technically termed "unions." The one gutter receives the yeast from the series of unions and conveys it to the proper receptacle. The yeast from these unions is found to make far better bread than that skimmed from large fermenting tuns. The reason is that the yeast gets thoroughly aerated during its flow down the side of the cask. For baking purposes, the thorough aeration of yeast is essential.

388. Employment of Brewers' Yeast.—Brewers' yeast is used in the production of what is called "farmhouse" bread: it is supposed to produce a sweeter flavoured loaf than do other varieties. On the other hand, brewers' yeasts darken the colour of bread. For reasons explained in the preceding chapter, for bakers' purposes, brewers' yeast is weak, and if used alone must be employed in considerable quantity. Almost invariably a potato ferment, or some substitute therefor, is employed together with brewers' yeast. It is apt when freely used to impart a bitter taste to the bread: this may be in part obviated by washing the yeast, but even then it is exceedingly difficult to remove the bitter taste. Particularly in summer time brewers' yeast is found to be very unreliable and uncertain in its actions. Even those bakers who prefer brewers' yeast, when they can procure it good, find themselves compelled to resort to compressed yeast during the hot summer months.

In selecting a brewers' yeast for bakers' purposes, those breweries should be avoided where large quantities of sugar or other malt substitutes are used instead of malt itself. Such brewing mixtures contain a deficiency of appropriate nitrogenous matters, and, although the resultant beer is sounder, and better meets the present requirements of the public, the yeast produced is, from the bakers' standpoint, weak and impoverished through ill nourishment.

389. Microscopic Examination of Yeast.—This operation requires a fair amount of experience before a trustworthy judgment can be formed. For the examination of yeast under the microscope, it should be diluted with water until so weak as simply to give a milky appearance to the water. A minute drop is then put on a slide, over which a cover is gently placed. In microscopically examining yeast, there are two distinct points to be observed: first, the presence or absence of disease ferments, *bacteria*, etc.; second, the appearance of the yeast cells themselves. For satisfactory work, a power of six or eight hundred diameters is necessary: the objective must be a good one, giving not only magnification, but also clear and accurate definition. It is a good plan to use a microscope in which several objectives are fastened to one "nose-piece," so that the powers may be changed instantaneously, without the trouble of unscrewing the one objective and then replacing it by another. Working with such an instrument the yeast may first be examined with a magnification of about 440 diameters, and then, having seen the aspect of a fairly large field, a few typical cells may be observed more closely with a magnifying power of about 1000 diameters.

First, with regard to the presence or absence of foreign ferments. The fewer of these the better the yeast. A yeast for bakers' purposes needs to be judged by a somewhat different standard to that adopted by the brewer. To the latter, the presence of lactic or butyric ferments or other disease organisms means that, during the period the beer is stored before it is all consumed, there is ample time for changes to go on which will result in either a marked deterioration or spoiling of the beer. But if this change does not make itself perceptible until, say, two or three weeks have elapsed, it follows, as bread is fermented, baked and eaten within about three days, that under ordinary circumstances such changes cannot take place in bread. This explanation is necessary, because it is well known as a matter of fact that many bakers do succeed in producing very good bread, who use a yeast in which there is frequently an abundance of foreign organisms. It will in such cases, however, be found that they take special precautions which serve to prevent an injurious action of these during fermentation. Summing up, yeasts may be used by bakers which could not possibly be employed by the brewer, because the fermenting process of the former is so much shorter; nevertheless an excess of disease ferments may set up injurious action even during the time of panary fermentation unless special precautions are taken. It is consequently safely laid down that the fewer of these foreign organisms the better. The presence or absence of disease ferments affords a valuable indication as to the previous history of the yeast, apart from their own specific action on the dough. A yeast largely contaminated with foreign organisms has been badly made: unsound malt will very likely have been used for its manufacture, and the whole process of fermentation conducted in dirty vessels. As in a brewers' yeast the presence of disease ferments tells us this of its previous history, the yeast should be condemned, because, when carelessly produced under such unfavourable conditions, the yeast itself is likely to be unsound, or at least very uncertain in its quality.

Secondly, with reference to the yeast cells themselves, the actual shape of the cells will vary with its origin. Ordinary English brewers' yeast consists of round cells, but Burton yeast is oval; so also is that in other districts where very hard water is used. With any yeast the cells should be about equal in size; not irregular, with some very large and others small. The cells should be isolated, or at most only attached in pairs: where they occur in large colonies, the yeast is too young, and has not had time to thoroughly mature. The cells should appear plump and not shrunken. The cell-walls should be of moderate thickness: if very thin the yeast is too young and has not attained maturity; on the other hand, very thick integuments denote an old, worked out yeast. Thin cell-walls may also be due not only to very young yeast, but also to the yeast being over kept long enough for the breaking down of the walls to have commenced: under these circumstances the protoplasm of the interior of the cells is seen to be broken down and frequently exhibits a "Brownian" movement. If in this condition, the yeast is far gone, and will be found weak and exhausted for bread-making. As in this operation yeast does not bud or reproduce, but does its work in virtue of the energy and vitality of the original cells introduced, it is in the highest degree important that these cells should be strong, healthy, and, as far as is possible, in full maturity; when in this condition, the contents of the cells should show slight granulations. Each cell should have one, or at most two, vacuoles; but when placed in a drop of clear beer wort on the slide, the fluid should rapidly penetrate the cell-walls, causing the contents to become lighter, and the vacuoles to disappear. These changes occur but slowly in old cells that have been worked for a long time.

In Plate II., Chapter IX., illustrations have already been given of different varieties of yeast employed by the baker. The drawings of brewers' yeast for this plate were made in the summer, and represent samples of brewers' yeast during practically the hottest weather of the year. The specimens marked *a* and *b* were taken from two London samples of yeast, as sold to London bakers by yeast merchants. A considerable number of disease ferments are present in both, marking them as being in an unhealthy condition. It is to be feared that often sufficient care is not taken for the storage and preservation of yeast, especialy during the hot weather, by those who collect brewers' yeast for redistribution among bakers. For purposes of comparison, some yeast was obtained from a Brighton brewery: this is figured in section *c*. It was found to be far away purer than either of the London samples; one or two *bacteria* are shown in the sketch, but there were several microscopic fields that contained no foreign ferments whatever. In general aspect, the cells of yeast *c* were firmer in outline, the walls being thicker while the interior matter showed more distinct and darker granulations. It should be added that in these drawings the estimated magnification is only approximate. In every case where it is wished to ascertain exact dimensions, the eye-piece micrometer should be called into requisition.

MANUFACTURE OF COMPRESSED YEASTS.

390. These yeasts are now so widely and successfully used that an account of their origin and mode of manufacture claims a place in this work. They are not, as has been stated, low or bottom yeasts of lager beer fermentation, but are distillers' yeasts, and are formed as the principal product in the manufacture of spirits from malt and raw grain; the spirits being used in the manufacture and treatment of liqueurs, perfumes, wine, and brandy. The manufacture can only be successfully conducted on a very large scale, and cannot be imitated by the baker who simply wishes to make yeast for his own consumption.

Being desirous of giving as accurate an account as possible of some of the most advanced and scientific methods of manufacturing compressed distillers' yeast for bakers' purposes, the authors put themselves in communication with the directors of the Netherlands Yeast and Spirit Manufactory of Delft, Holland. In response they received an invitation to visit the factory and personally inspect the processes of manufacture. The following description is compiled from information thus gained, supplemented by data furnished for the purpose by the directors of the factory.

The operations of yeast manufacture resolve themselves into four groups which may be classified under the following heads:—

1. Treatment of the raw grain, including the malting of barley.
2. Mashing and preparation of the wort.
3. Fermentation.
4. Collection and packing of the yeast.

(1) *Treatment of the raw grain.* The grain required is brought by barge and directly discharged by elevators into granaries provided for that purpose. For yeast and spirit manufacture, there must be a sufficiency of appropriate protein matter, and also of carbohydrates. Brewing sugars are inadmissible, because by unduly reducing the proportion

of protein matter, they would cause the production of an unhealthy and weak yeast. The cereals most commonly used are barley, rye, and maize. Rice is not well fitted for yeast production, because of its comparatively non-nitrogenous character. The grain on arrival is first subjected to such cleaning operations as may be necessary, including gravity separations of lighter and heavier foreign matter, and then a thorough washing. The cleaned grain is next conveyed to the mill, where the rye and maize are reduced to a moderately fine meal by roller mills. The barley is first converted into malt. In order to effect this object, two separate systems are in use.

Ordinary Malting System. On this, known also as the old system, the barley is first soaked in water of a suitable temperature in large tanks. When sufficiently moistened, which operation may take from fifty to sixty hours, the grain is transferred to the malting floors and there allowed to germinate or sprout. As previously explained, this treatment destroys the parenchymatous cell- walls, and thus renders the interior of the grain more readily amenable to diastatic action. At the same time diastase itself is developed, and the nitrogenous matter rendered more soluble. When germination has proceeded sufficiently far, the malt is dried in kilns. The malt kilns are conical buildings in which the grain is laid on perforated plates. At the base the source of heat is fixed and consists of a species of grate in which the fuel is consumed. By means of a fan placed at the top of the kiln, a current of air is continually drawn through the grain, which is thus effectually dried.

Pneumatic Maltings. On this system the malt floors are replaced by revolving drums, which are charged with barley. Air saturated with water is led into the drums and thus moistens the grain. Germination proceeds under efficient control, and when it has proceeded sufficiently far, the malt is conveyed to kiln-drums and there dried by means of heated air.

Whether prepared by the old or floor-system, or pneumatically, the finished malt is ground to meal.

(2) *Mashing and preparation of the Wort.* The meal of the raw grains, maize and rye, is treated by boiling with water in large boilers by the action of high pressure steam. When thoroughly cooked the mixture of grain and water is cooled and passed into the saccharification tuns, where the malt is added. Mashing then proceeds until the hydrolysis of the whole of the carbohydrates to maltose is as complete as possible. While the brewer finds it advantageous to retain dextrin and some amount of malto-dextrins in his wort, the distiller has practically no use for anything except the maltose, and so pushes the enzymic action to its utmost limit. At the close of the mashing the wort requires to be reduced to the fermenting temperature. It is important that this be effected as rapidly as possible, as the intermediate cooling stage is one at which the wort is most susceptible to disease fermentation. For this purpose, refrigerators are employed, of which there are several patterns. One of the most convenient is that originally devised by Lawrence, in which a copper pipe is bent again and again on itself so as to form a vertical rack, with connected horizontal pipes in a series one over the other. Cold water passes through the pipe, and the wort is allowed to flow over the outer surface, thus being rapidly cooled and at the same time aerated. The cooled wort is then conveyed to the fermentation vats, where it awaits the next stage in the process of manufacture.

(3) *Fermentation.* Of late years, the necessity of starting fermentation with a pure yeast culture has been more and more fully recognised. As explained in a previous chapter, paragraph 330, certain races of yeast are specially adapted for dough fermentation. For the preparation of these a specially equipped chemical and biological laboratory is provided. By appropriate methods, such yeasts are cultivated from a single cell until an appreciable quantity is obtained. In larger apparatus constructed on the principle of the Pasteur flask, a more abundant growth of the pure yeast is obtained, and this is used in starting the fermentation of the wort. The finished yeast is similarly controlled by tests as to purity and strength made in the laboratory; and as occasion arises, the pitching yeasts are reinforced by addition or substitution of new pure culture yeast. The firm employs two distinct methods of fermentation, known respectively as the "Vienna" and the "Aerating" systems.

Vienna System. The first step in this system is the preparation of what, in the bakers' phraseology, may be termed a "ferment," that is, a preliminary fermentation of a relatively small proportion of the grain. Malt and rye are taken together for this purpose, and mashed at a convenient temperature, so as to obtain as complete a transformation as possible of the starch into maltose. The mash thus produced is allowed to stand in the tubs at a temperature most suitable for the production of lactic acid, that is, about 35° C. The lactic acid germs on the skin of the malt rapidly develop, and a marked acidulation ensues. This is a most interesting step in the fermentation, and while the immediate result is the production of lactic acid, yet its ultimate effect is the prevention of development of the lactic acid ferment. This organism is peculiarly sensitive to the effect of its own product, and as little as 0.15 per cent. of lactic acid added to a mash is sufficient to prevent lactic fermentation taking place, although, on the contrary, if lactic fermentation be once started, it will proceed until something like 1.5 per cent, of lactic acid has been formed. The reason of this inhibitory effect is that the addition of lactic acid is a deterrent not only to lactic fermentation, but also to the multiplication of lactic acid *bacteria,* so that, by its addition in the earlier stage, any reproduction of these organisms, and consequently any but the smallest possible production of lactic acid, is prevented. This first development of lactic acid, then, in what may be for convenience called the "ferment," serves to check undue development of acidity in the main fermentation. It also further serves the useful purpose of peptonising and otherwise breaking down the nitrogenous matter of the grains in the mash, so as to render them available as yeast foods.

The unfiltered wort, containing the "grains" or husks of the malt and the raw grains, is treated at the desired temperature with pitching yeast in the form of the ferment already described. Air is driven through the wort by mechanical means in order to secure thorough aeration, and this operation is repeated from time to time as fermentation proceeds, as found necessary. The grains contained in the mash rise to the surface and there act as a non-conductor of heat. In from three to four hours after pitching, the carbon dioxide forces itself up in a sort of cauliflower head through the grains and "breaks." The grains are removed by a skimming operation, and fermentation is allowed to continue for from ten till twelve hours from the commencement, and then the process of skimming off the yeast is commenced. The skimming is effected by means of a long arm which sweeps right round the vat and collects the yeast from the top into an inverted cone, which from its shape is called a parachute. The alcohol from the fermentation remains in the wort, which liquid is distilled, and the alcohol thus obtained in a concentrated form. The residual liquid, together with insoluble matter consisting principally of fibre from the grains, is prepared for, and used as, cattle-food. The following figure, No. 23, shows diagrammatically the "Vienna" method of yeast manufacture.

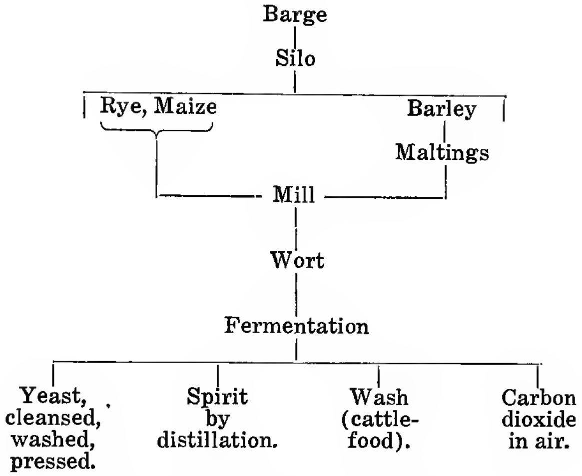


Fig. 23.—Vienna System of Yeast-Making.

Aerating System. By this method, the wort is filtered from the grains before fermentation. The pitching or starting yeast is added to the clear wort, through which a strong current of air is forced. The yeast as produced does not rise to the surface of the fermenting wort, but sinks and forms a deposit on the bottom of the vats or tuns. At the close of the fermentation, the supernatant clear liquid contains the alcohol, and is removed for purposes of distillation. The residual liquid, together with the filtered grains, is prepared for use as cattle-food. The course of the various operations of the "aerated" system is shown diagrammatically in Fig. 24.

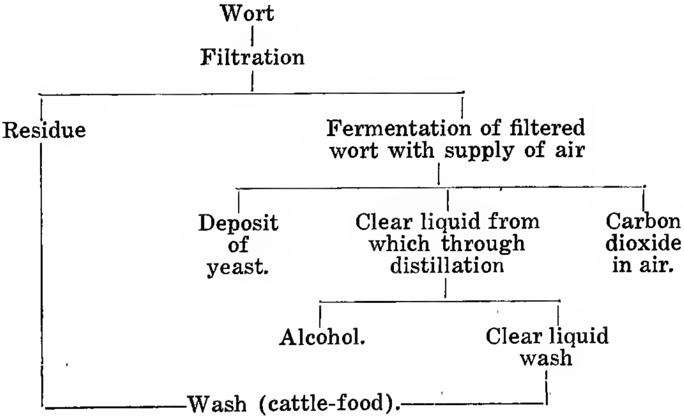


Fig. 24.—Aerated System of Yeast-Making.

(4) *Collection of the Yeast.* The yeast, whether skimmed on the old system or deposited on the new, has to be cleansed. For this purpose it is mixed with water and passed through a series of sieves (20 holes to the square millimetre). The sieves retain any grains and allow the yeast to pass through. The yeast is then washed by decantation, and allowed to settle. Any minute particles which have passed through with the yeast, being lighter than water, rise to the surface and are thus separated. The deposited yeast, still containing much water, is passed through centrifugal machines by which much of the water is removed. The thick yeasty liquid is next pumped into filtering presses and thus obtained in the familiar dry state. The yeast is now ready to be packed, and for the British market is filled into jute bags, which are mechanically pressed into block shape and finally branded with the name and description of the manufacturers. As thus prepared "N.G. and S.F." yeast consists of pure yeast cells of a specially selected type. It is practically free from foreign or "wild" yeast and also from bacteria.

The secrets of successful yeast manufacture are raw materials of the highest quality, absolute cleanliness during the whole process of manufacture, and finally eternal vigilance. This last is the invariable price of excellence in yeast. Cleanliness of vessels is ensured by washing and scalding with live steam. As an additional precaution, all vats and tuns are periodically treated either with sulphurous acid or bisulphite of lime, both of which are absolutely harmless and most efficient antiseptics. All floors are kept clean by continual rinsings with water, the pathways consisting of raised planks, under which the water passes freely. In the yeast-cleansing rooms, where, being in the quiescent stage, the risk of contamination is greatest, the floors and walls are continually treated with solution of chloride of lime, thus most effectively destroying all disease germs. Such is in outline the process of manufacture employed in the production of one of the most widely used and highest character yeasts imported from the continent into the United Kingdom.

391. Characteristics of Compressed Yeasts.—A good sample of compressed yeast has the following characteristics—it should be only very slightly moist, not sloppy to the touch; the colour should be a creamy white; when broken it should show a fine fracture; when placed on the tongue it should melt readily in the mouth; it should have an odour of apples, not like that of cheese; neither should it have an acid odour or taste. Any cheesy odour shows that the yeast is stale, and that incipient decomposition has set in.

Viewed under the microscope, compressed yeast consists of somewhat smaller and more oval cells than those of brewers' yeast. In the best varieties are found no, or only traces of, foreign ferments; other brands contain them in large numbers. The yeast cells themselves should possess the same characteristics as have already been described while treating brewers' yeast. A drawing of compressed yeast is given in Plate II. The cells were found, on measurement, to have the following dimensions—

Longer diameter	10 mkms.	= 0.0004 inch.
Shorter diameter	7.6 mkms.	= 0.0003 "
Diameter of round cells ..	7.6 mkms.	= 0.0003 "

The sample in question was remarkably free from disease ferments, one only being seen in the field sketched, while several fields showed no foreign organisms whatever. The granulations show very distinctly. The yeast in question was a very pure one, and yielded exceedingly good results when subjected to strength tests.

In general character, the compressed yeasts are steady and trustworthy in their action; they produce sweet, well-flavoured breads, to which, when in good condition, they do not impart any yeasty taste. Their good qualities stand out most distinctly in summer time, when other yeasts so frequently fail entirely to produce a satisfactory loaf of bread. Their being produced in such large quantity causes their manufacture to be entrusted to men who bring the highest skill that practical experience and science can furnish to bear on every detail of manufacturing processes. The many good properties of distillers' compressed yeast have led to its almost universal employment where obtainable, in place of other kinds of yeast.

"Patent," or Bakers' Home-Made Yeasts.

392. As already explained, these are now largely replaced by compressed yeast. But there are still districts where this is unobtainable, and where bakers must perforce prepare their own yeast. It is hoped that these will find the following paragraphs of service. Bakers' home-made yeasts may be divided into two varieties—malt and hop yeasts as used in England, and flour barms as employed in Scotland.

393. Bakers' Malt and Hop Yeasts.—These consist essentially of small mashes of malt and hops, fermented either by the addition of some yeast from a previous brewing, or allowed to ferment spontaneously: the latter is known as "virgin" yeast. The hops present tend to prevent disease fermentations, as their bitter principle is inimical to bacterial growth and development. In virgin yeasts, particularly, it is necessary to use hops largely, and also plenty of malt; as lactic and other foreign ferments flourish far better in a dilute saccharine medium than in a stronger one. The reader will already be familiar with the general outlines of the fermentation of a hopped wort: as an introductory to directions for the preparation of patent yeast a careful study of the following experiment, made by one of the authors, will be of service. The student will do well to repeat the experiment for himself: sufficiently full directions are therefore given to enable him to do so.

Take two quarts of water and half an ounce of good hops; set these to boil in a large glass flask or other *clean* vessel; boil for half an hour, and then cool down to 65° C. (149° F.). Scald out a large glass beaker, or failing this, a vessel of copper or enamelled ware; wood will not answer well. Weigh out 12 ounces of ground malt and mix with the hops and water in the beaker. Maintain the whole at a temperature of from 65° to 70° C. (149° to 158° F.) for two hours; this may be done by standing the beaker in a hot water-bath. By the end of this time the saccharification of the malt should be complete. Have ready another glass vessel perfectly clean and scalded. Strain the wort, from the grains, through calico into this second clean vessel; cool down as rapidly as possible to 25° C. (77° F.). In the meantime have ready a large water-bath, carefully regulated at a temperature of 25° C. by means of an automatic temperature regulator. Also thoroughly clean and scald six glass beakers of about 16 ounces capacity, and have ready glass covers for each beaker. Pour the filtered wort into these beakers, placing about an equal quantity in each. Label both beakers and covers with numbers from 1 to 6. Let No. 1 remain in the condition of plain wort; to No. 2 add 1 gram (15 grains) of good brewers' yeast; to No. 3 add 0.7 gram (10 grains) of good compressed yeast. Prepare Nos. 4, 5, and 6 in exactly the same manner, so as to form a corresponding set. Cover each beaker with its glass cover and stand the whole in the water-bath. Let the first series remain undisturbed, but aerate those of the second by, some five or six times a day, pouring the contents of each beaker into a clean empty beaker, and then back again several times. After each aeration replace the covers and stand the beakers again in the bath.

After about 24 hours examine each sample under the microscope. In the authors' experiment, No. 1 at that time, and also after three days, contained no yeast, while the whole liquid was swarming with *bacteria*; a slight froth had formed on the top. A portion of this wort was then sown in Pasteur's Fluid (Yeast Mixture), and again examined at the end of three hours, being maintained for that time at 26.6° C. (80° F.); it still contained no yeast. The student is recommended to employ a fermenting temperature of 25° C. This result was obtained not merely once, but also in a complete duplicate series of experiments. The mode of procedure is the same as that employed by those bakers who are in the habit of allowing their yeast to ferment spontaneously—except that chemically clean vessels are employed throughout. Another interesting point is that although yeast was being used in the room at the time, and even beakers, containing actively fermenting worts, were standing side by side in the same water-bath, yet the loosely fitting glass covers were sufficient to prevent the entrance of yeast cells or spores into beaker No. 1 from external sources.

Within twenty-four hours after being pitched, each sample was thus examined under the microscope. Nos. 2, 3, 5, and 6 were in a state of vigorous fermentation.

At the end of three days the yeasts were again examined, having been maintained at a temperature of 26.6° C. (80° F.) for this period.

After this lapse of time the fermentation had very nearly ceased. Instead of observing a field covered with perfectly new cells, the majority of which were actively budding, the aspect of the yeast is far more quiescent. Here and there an old cell is still to be seen. The new cells, however, have begun to assume somewhat the same appearance. In some of them vacuoles are to be seen, but only in a few. All the cells are more or less filled with faint, but distinct, granulations.

There is at the end of this time a marked difference in appearance between the pressed as compared with the brewers' yeast. The vacuoles show much more distinctly, so also the interiors of the cells are much darker.

Particular attention is drawn to the fact that whereas samples Nos. 1 and 4, which were allowed to ferment spontaneously, swarmed, after three days, with *bacteria*; the whole of the other four specimens which had been sown with yeast showed, on observation, no foreign ferments whatever. It is possible that some may have been discovered by careful and systematic examination, but the main point is that, compared with Nos. 1 and 4, they were to all intents absent. Now, save by the addition of yeast, all the samples were exposed to precisely the same conditions; the only conclusion to be drawn is that the presence of yeast growth is more or less inimical to that of foreign or disease ferments. The practical lesson to be learned from this is that bakers who prepare their own malt and hop yeasts, by sowing them with small quantities of pure yeast, not only induce a healthy growth of pure yeast ferments, but also retard the growth and development of disease ferments. The most probable explanation of this lies in the fact that, under the conditions of the experiment, there is a more or less acute struggle for existence between the two organisms, and yeast, being the more vigorous and hardy, grows and developes at the expense of the *bacteria*. (Compare with the views advanced in paragraph 377.)

After standing some time the vessels of yeast were covered with a film of *Mycoderma cerevisiæ;* a growth which has been described in Chapter IX., and illustrated in Fig. 15.

Nothing has as yet been said about the difference between the series of beakers that were allowed to remain undisturbed, and those which were aerated from time to time. Before doing so it would be well to describe the results of determining the amounts of gas evolved by the respective samples on being tested in the yeast apparatus. At the time these experiments were made, the older form of apparatus was employed, in which the gas bubbled up through the water.

After standing three days these samples of yeast were tested by being inserted in the testing apparatus. Half an ounce of yeast mixture was taken, to this was added six ounces of the thoroughly stirred yeast. At the end of three hours the following quantities of gas were found to have been evolved from each:—

	Cubic Inches.
No. 1. Spontaneous ferment, undisturbed	3.1
No. 2. Pitched with brewers' yeast, undisturbed ..	16.8
No. 3. Pitched with pressed yeast, undisturbed ..	35.6
No. 4. Spontaneous ferment, agitated	3.7
No. 5. Pitched with brewers' yeast, agitated ..	18.6
No. 6. Pitched with pressed yeast, agitated	42.8

The experiment shows very clearly that the agitation has resulted in the yeast being in every instance more vigorous in action. In the case of the spontaneous ferment there was a distinct, though slow, evolution of gas. The samples pitched with the pressed yeast had, by the by, more than twice the capacity for causing the evolution of gas than had those which were pitched with brewers' yeast. It is plain that agitation in some way increases the vigour of yeast. Those students who have carefully read the section of Chapter IX. dealing with the influence of oxygen on fermentation, will clearly understand the cause of such increase in fermentative power.

When yeast is being made by bakers from malt and hops, although fermentation goes on, it is not the fermentation, as such, that is wanted. The change required is not the production of beer, but the growth and development of yeast; hence the operation should be so conducted as to induce the greatest yield of yeast in the most active and vigorous form. Aeration, or "rousing," as it is often termed, is, as will now be well understood, of considerable service. In brewing large quantities of yeast, it would obviously be difficult to aerate by pouring from vessel to vessel; the same object may be served by from time to time thoroughly stirring the fermenting yeast. This free access of air not only stimulates the growth of yeast, but in addition is inimical to the development of disease ferments; so much so, that by careful working with plenty of air a yeast can be made to give moderately good results, that would be absolutely unusable if fermentation were conducted in closed vessels. It follows that yeast is better brewed in comparatively shallow and open tubs than in deep and closed ones.

The careful performance throughout of this experiment will not only be an instructive exercise on fermentation, but will also afford good practice with the microscope.

394. Formula for Manufacture of Malt and Hops Patent Yeast.—The following formula for the manufacture of patent yeast is taken from "The Miller,"—40 gallons of water and 2 lbs. of sound hops are boiled together for half an hour in a copper, and then passed over a refrigerator, and thus cooled to a temperature of 71° C. (160° F.). The liquor passes from the refrigerator to a stout tub; 1½ bushels (about 63 lbs.) of crushed malt are then added, and the mixture thoroughly stirred. The mash is allowed to stand at that temperature for 1½ hours, filtered from the grains, and then rapidly cooled to 21° C. (70° F.). The passage over the refrigerator serves also to thoroughly aerate the wort. Spontaneous fermentation is then allowed to set in, and the yeast is usually ready for use in 24 hours, but is in better condition at the end of two days. All fermenting tubs, and other vessels and implements used, are kept clean by being from time to time thoroughly scalded out with live steam. The result is the production of a yeast of very high quality. Or fermentation may be started by the addition of a small quantity of good yeast.

395. Suggestions on Yeast Brewing; what to do, and what to avoid.—The quantities given above are larger than those required by many bakers, but the formula may be adopted for smaller brewings by taking a half, or quarter, or some other proportion of each ingredient. In connection with brewing, the first consideration is the room; this should not be in the same part of the bakehouse as the ovens. Select, if possible, a room having an equable temperature of from 65 to 70° F. Stout tubs of appropriate size should be used for brewing; these should be about the same width as depth. Before commencing, clean all tubs and implements with boiling water. The hops are better boiled in a copper; iron vessels are apt to discolour them, especially if the vessels are in the slightest degree rusty. Let the hop liquor cool down to the temperature given, *before* adding the malt, as a temperature much higher than from 65 to 70° C. destroys the diastatic power. On no account *boil* the malt: some bakers place malt and hops together, and boil the two, under a mistaken idea that they get more extract from the malt. The result is that diastasis is arrested long before the whole of the starch is converted into dextrin and maltose. For the same reason, fifteen minutes is too short a time for the mashing to be continued. The baker not only requires to saccharify his malt, but it is also necessary for him to convert as large a proportion as possible of his dextrin into maltose. This is hindered either by using too high a temperature, or mashing for too short a time. Starting with a mashing liquor at 65 to 70° C., and mashing for from 1½ to 2 hours, gives about the best results. The cooling after removal from the grains, which may be washed or "sparged" with a small quantity more water, must be done quickly, so as to have the wort for as short a time as possible at a temperature of from 35 to 40° C., as at that temperature bacterial fermentations proceed most vigorously. The wort at 21.5° C. (70° F.) may either be pitched with a small quantity of yeast reserved from the last brewing, or by the addition of a small quantity of good fresh compressed yeast. If wished, the fermentation may be allowed to set in spontaneously, as suggested in the preceding paragraph, in which case a "virgin" yeast is produced. It is doubtful, however, whether this is to be recommended in most cases. The risk of spoiled yeast is greater, and at times alcoholic fermentation does not set in at all, or too late to prevent its being preceded by excessive lactic and other foreign fermentations. The temperature should not be allowed to rise, during fermentation, much above 21 to 22° C. In summer time there is a great tendency for a rapid rise to set in; this may be controlled by placing an attemperator in the wort, and passing a stream of cold water through. An attemperator consists of a properly arranged series of pipes, through which hot or cold water at will may be passed. Temperatures must in all cases be got right by actual use of the thermometer. From time to time, stir the fermenting wort so as to rouse or aerate it. When the yeast is made, keep it freely exposed to air. In making patent yeast it is very poor economy to stint either malt or hops: a weak wort produces a much less healthy and vigorous yeast than does a strong one, besides being much more subject to disease fermentation, and consequent acidity. And, when made, the dilute yeast shows no saving, because so much more of it has to be taken in order to do the same work.

396. Specific Gravity of Worts, and Attenuation.—In addition to taking the temperature of his worts, the brewer also tests the density or specific gravity of each sample. This is done as a means of estimating the amount of soluble extract obtained from the malt. The maltose and other soluble carbohydrates, yielded on mashing, increase the specific gravity of the wort. Taking the density of water as 1000, each gram of carbohydrate in 100 c.c., or, what amounts to the same thing, each lb. of carbohydrate in 10 gallons of the wort increases the density of the solution by 3.85. Thus, suppose that a wort is found at 15.5° C. (60° F.) to have a specific gravity of 1011.5, then

$$\frac{1011.5 - 1000}{3.85} = 3 = \text{weight in lbs. of}$$

sugar and other solid matter in 10 gallons of the clear wort. As the density of a liquid varies with its temperature, all densities are best taken at the uniform temperature of 15.5° C.

The Inland Revenue Act of 1880 assumes that 2 bushels of average malt, weighing 84 lbs., will produce a barrel (36 gallons) of wort having a density of 1057. Accepting this estimate as correct, and assuming that the 40 gallons of water employed in the previously given recipe, together with the small extra quantity used in sparging or washing the grains, yield after loss through evaporation 40 gallons of wort; then the wort produced ought to have a density of 1038.3, which is equal to almost exactly 10 lbs. of solid extract per 10 gallons of wort. Working with comparatively imperfect methods, and in small quantities, the baker can not expect his malt to yield the full extract, but as a matter of practice he ought at any rate to get nothing less than a density of 1030. One of the most important sources of loss arises from imperfect sparging of the grains; these should be washed once, and may then with economy be put into a small press and squeezed dry. Of course, if with extra washing water the volume of the wort is increased, then the density will naturally fall. Testing the density of his wort is not only of importance to the baker, as a measure of the degree of efficiency with which he is extracting the valuable matters of his malt, but is also a test, of the highest value, of the regularity of his work. If one day a wort of comparatively high density is being attained, and on another one of low density, something is wrong, and must be righted. The baker should always endeavour to have his worts at the same density when ready for pitching: 1030 may be taken as a very good standard to work at. If it is found in practice that the densities fall below this, mash with comparatively less water; if the densities run too high, dilute the wort with water until of the right density before pitching. The necessary quantity of water to add may be easily calculated, on remembering that the volume of the wort is in inverse proportion to the density, less 1000. Thus, supposing that the 40 gallons of wort are found to have a density of 1035, then

as 30 : 35 :: 40 : 46 gallons.

The wort will have to be made up to 46 gallons, therefore 6 gallons of water must be added. The quantity of wort produced should always be measured; to do this, determine once for all the capacity of the fermenting tubs in the following manner:—Prepare a staff about an inch square; pour water into the tub, gallon by gallon, and at each addition put in the staff and mark on it the height of the water. This operation once completed, the quantity of wort made can at any time be determined simply by plunging the staff into the tub and reading off the number of gallons as marked on it.

For practical purposes, the density of a wort is best determined by a hydrometer; this instrument is made either of brass or glass. It has a weighted bulb at the bottom, and a long graduated stem; accompanying the hydrometer is a tall glass jar, known as a hydrometer jar. Fill this jar with wort at the right temperature, and place in the hydrometer; as soon as it comes to rest, read off the graduation which coincides with the level of the liquid; the number gives the density. For the baker, the most convenient hydrometer is one graduated in single degrees, from 1000 to 1040. The hydrometer is also sometimes known as a saccharometer.

As fermentation proceeds, the density of the liquid becomes less, and at the same time it loses its sirupy consistency—hence the brewer states it to have become "attenuated."

397. Microscopic Sketches of Patent Yeast.—In Plate II. are given microscopic sketches made of patent yeasts collected in the South of England.

The sketches marked respectively *a* and *b* were drawn from samples of patent yeast, both obtained in the same town, but from different bakers, during the summer. The sample marked *a* was evidently prepared in a strong wort; in fact, at the time of examination the yeast was still sweet through presence of maltose in considerable quantity, and had a high density. The yeast was not free from disease ferments, but still compared remarkably favourably in this respect with all other samples examined. One specially noticeable point about the sample was the elongated shape of the cells; some were not merely ovoid, but even decidedly pear-shaped. One sketched shows this peculiarity in a very marked manner. This yeast was at the time yielding very good results; the bread was sweet and of good flavour. One is in doubt with regard to sample *b*, whether it should be viewed as an example of alcoholic or bacterial fermentation; certainly the latter ferments are about as plentiful as yeast cells. The yeast contained very little either of maltose or hops; in fact, it had evidently been brewed with as little as possible of these ingredients employed. Readers will probably not be surprised that yeast *a* produced a far superior loaf of bread than did yeast *b*. The sample *c* is likewise of considerable interest; it was also taken during the summer. The baker was in the habit of, at the close of his yeast brewing, setting aside a portion for the purpose of pitching his next lot of wort. This pitching yeast was stored in a corked bottle. This also was a yeast brewed in a poor wort, although not so bad as sample *b*. Notice particularly, in *c*, the chain of elongated cells; these are often noticed in yeast grown without sufficient aliment, and the sketch shows a striking example.

SCOTCH FLOUR BARMS.

398. Parisian Barm, Montgomerie.—Mr. J. Montgomerie, of Glasgow, has furnished the authors with the following account of the manufacture of Parisian barm as now conducted in Scotland.

"Sixteen Scotch pints (of two Imperial quarts each) of water at 164° F. are mashed with 24 lbs. of crushed malt for from 3½ to 4 hours, standing in a warm place so as to ensure as little loss of temperature as possible. It is then transferred to a malt press, and the wort drawn off. The wort, with the exception of 3 pints, is put in the tub, and 3 pints of water added at a temperature to bring it up to 120° F. (You have 13 pints of wort and 3 pints of water, making 1½ lbs. malt to the pint of water). Put in 112 lbs. flour. A good barm flour is a blend of flour obtained from spring and winter wheats in about equal proportions. The wort and flour are then stirred into a batter. Forty pints of boiling water are then stirred in, 4 pints at a time. The starch in the flour will gelatinise at the thirty-second pint. The last 8 pints are added when it begins to liquefy. The 3 pints of wort are then added.

To take off a scald with a

4	pint mash,	the temperature of	the wort is	140	degrees F.
6	”	”	”	134	”
8	”	”	”	132	”
10	”	”	”	130	”
12	”	”	”	126	”
14	”	”	”	124	”
16	”	”	”	120	”
20	”	”	”	120	”
24	”	”	”	120	”
30	”	”	”	116	”
35	”	”	”	110	”
40	”	”	”	100	”

The last is the biggest taken off in any factory.

"The scald is then cooled until the temperature drops to between 80 and 90° F. in winter, and 60 and 70° F. in summer. If the Barm Cellar is kept at a constant temperature of, say, 56°F., then 80° F. is a very good temperature to scald at.

"*Storing the Scald.* Take the temperature of the scald and add 13 pints of matured barm as a store, *i.e.,* 1 pint of barm to 4 pints of scald. (As may be gathered from the preceding description, the "store" is a portion of old barm added for the purpose of pitching, or starting fermentation.) Allow it to lie for 3 or 4 hours, then divide into two or three suitable vessels and remove to the Barm Cellar, which should be large and airy, to ferment. The barm will come up its height in 18 hours, and then gradually settle down with a clear round bell on the top on the second day of fermenting. On the third day it will begin to clear off, and on the fourth will be cleared off. The barm is now ready for using, but most bakers prefer to allow it to mature to the fifth day, as it gives a better flavoured loaf, and the fermentation of the dough is more easily controlled. In the event of the barm showing signs of hardness, decrease the quantity of malt used at mashing, and if of greenness, increase the quantity of malt.

"To keep barm right, it is essential that everything should be kept scrupulously clean, with a plentiful supply of fresh air, and that the barm be stored and kept at a constant temperature."

399. Scottish Barms, Meikle.—Mr. J. Meikle, the well-known baker and writer on bread-making, has supplied the following information on Scottish barms, for which the authors express their acknowledgments and thanks. The various data were submitted by Mr. Meikle to a number of bakers in Scotland, and may therefore be taken as thoroughly reliable in every way.

Compound Barm.

40 lbs. Water.
10 lbs. Malt.
4 lbs. Store.
4 oz. Hops.
2 oz. Salt.
Mash 3 hours.

"Compound Barm is not now used to the extent it was at one time, but many of the older bakers agree that it is *the* barm for flavour in bread. Take 10 lbs. of water and mix in the hops, bring the water to the boil and allow to simmer for a few minutes. Transfer this to a 5 gallon tub and add 30 lbs. of water at 180° F. to make up to 40 lbs. Throw a flour bag over the tub and allow the liquor to cool to 164° F., then stir in the malt, cover up the tub well, and keep it in a warm corner for about three hours. At the end of that time run the 'mash' into a barm press and press out all the liquor. Cool this as quickly as possible to 72° F., stir in the store and the salt, then set the whole to ferment for 36 hours. At the end of that time the gas should all be gone; it should in fact have ceased to hiss: if hissing still goes on the barm must not be used as it is not ready. Some Scotch bakers will not touch this barm until hissing ceases, but a good rousing stir will help matters considerably.

"I have used pounds in connection with liquor, and will use this system in what follows for the reason that the Scotch 'pint' does not always mean a definite quantity. It generally means half an Imperial gallon, but often it means a real old Scotch pint, which is equal to about 3 Imperial pints or almost 4 lbs. avoirdupois. An Imperial gallon of water weighs 10 lbs. avoirdupois, so that the figures given divided by 5 give the number of Scotch pints (half gallons) as generally in use, and divided by 4 give old Scotch pints.

Virgin Barm.

20 lbs. Water at 125° F.
32 lbs. Flour.
45 lbs. Water at 212° F.
10 lbs. Store.

"To lie 12 hours before 'Storing,' or till it falls to 80° F.; 60 hours afterwards it will be ready.

"Mix the water at 125° F. with the flour into a stiff paste by hand, making sure that boiling water is immediately afterwards available. Scrape down the batter in the inside of the tub, then, add boiling water 2 pints at a time (a gallon) stirring vigorously between each addition with a stick of the nature of a broom handle. The mixture will be easy to stir at first, but when the starch cells begin to burst it will 'grip,' and care must be taken, first, to keep clear of lumps, second, not to add too much water. The strength of the final barm depends on the solids, not upon the amount of water added. The scald must now lie for about 12 hours, when it will have not only become cool, but also thin, and slightly tart (acid). Now add the store and a handful of flour, stir well and allow to ferment for 56 hours. Foaming will start at the sides and will gradually cover the top: if a ring still remains in the centre when the barm is to be used the baker must make up his mind for weak fermentation. Real Virgin Barm is not stored at all, but I have never seen such barm worked. Virgin, so called, has been gradually displaced by Parisian, but I have seen it used many years and have seen much good bread made from it.

Parisian Barm.

15 lbs.	Water	mash at 160° F.
3¾ lbs.	Malt	
22 lbs.	Flour.	
35 lbs.	Water at 212° F.	
10 lbs.	Store.	

"To lie 12 hours before storing or until it reaches 76° F.; ready 50 hours afterwards.

"This is *the* barm of Scotland today and is made as follows: Mash the malt and water as for compound barm; that is, measure the water in a clean tub at a temperature of about 180° F., cover this up and allow the temperature to fall to 162° F., then add the malt. The reason for using water at 180° F. is to ensure the tub being thoroughly warmed up: by well covering up after mashing the proper temperature is kept up for a longer period—the subsequent barm will be no good unless care is exercised at the very start. In two and a half hours wring off the liquor and add sufficient water at 150° F. to bring up the total to 15 lbs. and the temperature to 128° F., stir in the flour by hand, and afterwards add the boiling water, and stir vigorously as already described for Virgin barm. The scald should not be so stiff as for Virgin, and should taste sweet when newly made. It begins to thin almost immediately, and as it lies gets a little sharper in taste; it should not, however, be cooled artificially. When storing stir vigorously and well. Parisian barm while fermenting behaves like a thin ferment made with distillers' yeast, sugar and a handful of flour, only the bells or gas bubbles are larger and brighter. The barm has the strength, without the "rampness," of compound, and the mildness without the weakness of Virgin. Of suitable barm flours more further on. In the making of scalds in large places machinery has been utilised. The stirring machine is used with success in making large scalds in the factories, such scalds being afterwards divided amongst several tubs for fermenting purposes." (*Personal Communication,* October, 1910).

CHAPTER XIII.

PHYSICAL STRUCTURE AND PHYSIOLOGY OF THE WHEAT GRAIN.

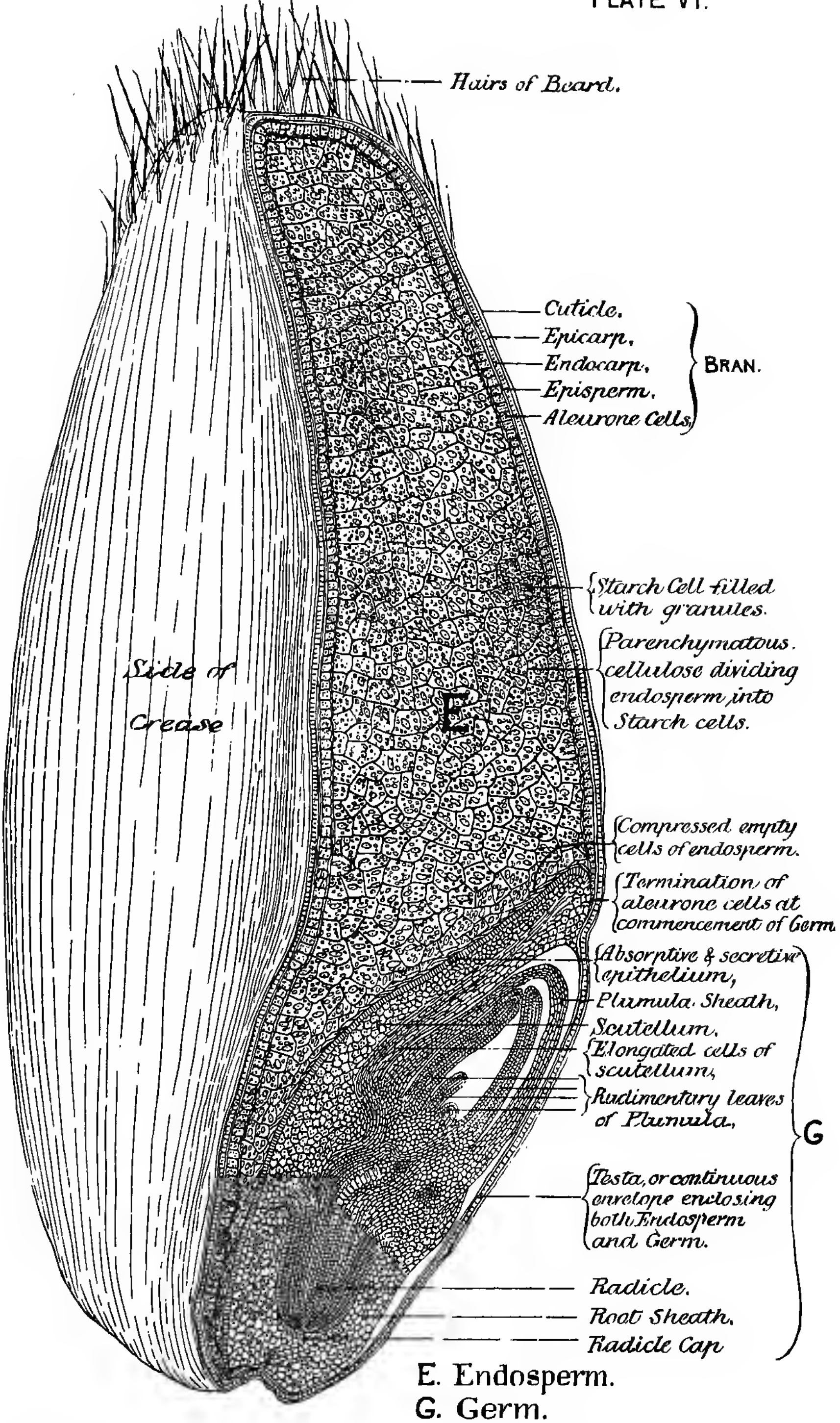
400. Functions of the Wheat Grain.—The wheat grain is that part of the plant on which falls the task of performing the functions of reproduction, hence all its parts are specially adapted to that purpose. The germ, or embryo, of wheat, really the true seed, is that portion of the grain which ultimately develops into the future plant. The main body, composed principally of starchy matter, is termed the "endosperm": its function is to supply the germ with food during the first stages of its growth. Besides these there are the various outer and other coverings, destined for the adequate protection of the seed, which together constitute the bran. The physical structure of the wheat grain requires for its systematic study the use of the microscope: the descriptions following therefore include practical directions for microscopic observation. The arrangement adopted is that most easily followed by the student in a course of actual microscopic work. For earlier studies it is well to obtain from the dealer ready-mounted longitudinal and vertical sections of a grain of wheat. In every case, practise sketching what is seen: as before stated, the accompanying figures are facsimiles of those which the student should himself make.

401. Longitudinal Section of Whole Grain.—In the first place, examine the longitudinal section of the grain of wheat with the 3-inch objective; the whole of the grain will then be in the field. Try, in the next place, to make a sketch of it. For this purpose the student should use a camera lucida if he should possess one. Trace in the outline and other principal lines with a hard pencil; then go over them with a lithographic pen and liquid Indian ink. It will be impossible to get in all the details; the effort should be rather to show what is essential; thus the object of the sketch with the low objective is to get an idea of the general shape and arrangement of the different constituent parts of the grain. When the drawing is complete, mark underneath the number of diameters to which it has been magnified.

In Plate VI. is given a section through the crease of the grain, which is shown in elevation by shading on the left-hand side of the figure. The whole of the figure has been obtained by careful tracing in the authors' laboratory from typical slides, and is throughout a faithful representation of the grain. The germ is seen at the lower end of the figure, and a fair idea of its size, compared with that of the endosperm, which constitutes the remainder of the grain, may be obtained. Enclosing both germ and endosperm is the bran. With the low power, which the student has been directed to use, the square cells of the bran lining the interior, and known as aleurone cells, are just visible. The name commonly given to these is, by the by, a misnomer; they are not "gluten" cells, for the reason that they contain no gluten. The more minute examination of the grain is best made by the aid of the higher powers, and shows more of the details drawn in Plate VI., to which reference is made in the paragraphs which follow.

The various parts of the grain are fully indicated on the plate itself.

PLATE VI.



LONGITUDINAL SECTION THROUGH A GRAIN OF WHEAT.
Magnified about 20 diameters.

402. Transverse Section of Wheat Grain.—Examine next a transverse section of a grain of wheat; the section, below figured, Fig. 25, was cut from a grain of Kubanka wheat, and passes through the germ.

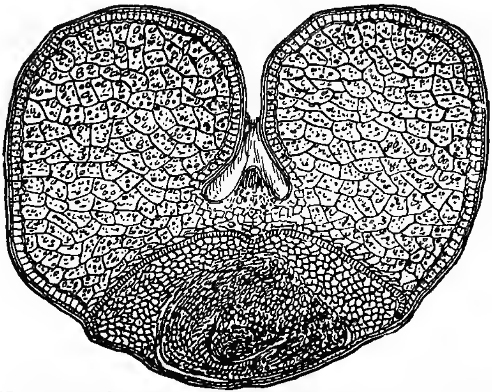


Fig. 25.—Transverse Section of Grain of Wheat, magnified 13 diameters.

On examining carefully such a section as that shown, the pigment-containing cells are seen in a line passing completely round the grain, and forming a thick spot of colour in the crease. Notice that the aleurone cells of the bran do not continue round the germ. Observe also as much as possible of the structure of the germ itself, and the relative dimensions and positions of germ and endosperm.

Examine the same section in the next place with the 1-inch objective (Fig. 26). The outer skins of the bran are here seen more plainly; the square aleurone or cerealin cells are also plainly visible. Notice that near the bottom of the crease, the cells, instead of being in single line, are in double, becoming more numerous and irregularly arranged as the bottom is approached. The crease distinctly bifurcates at the bottom; the pigment layer of the grain becomes considerably enlarged, and its section is seen at the middle of the fork as a dark yellow spot of considerable size. With this power the starch granules also become visible.

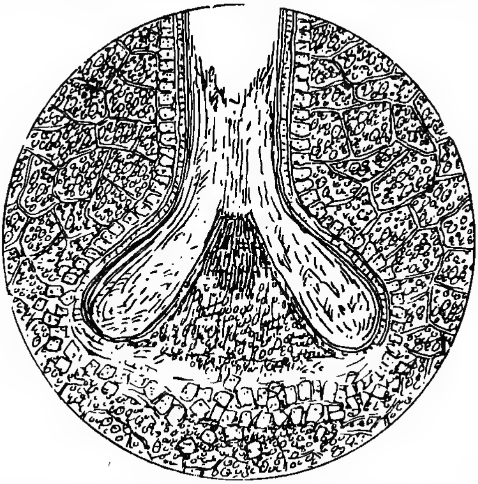


Fig. 26.—View of Crease in Grain of Wheat, as shown in a transverse section, magnified 110 diameters.

403. Section Cutting and Mounting.—It has been assumed that, for the purposes of making these studies and sketches, the student has had in his possession sections that he has purchased ready mounted. He will probably at this stage of his work wish to prepare and mount sections of his own. Wheat in its ordinary state is too brittle to permit of its being cut in thin sections. In the first place, therefore, soak a few grains in water for about twenty-four hours; the water may be luke-warm, say at a temperature of 80° to 90° F. When the grains have become moderately soft, sections may be cut from one of them. For this purpose a very sharp razor, which has been ground flat on one side, is generally used. Take one of the grains between the thumb and finger, cut off one end, and then proceed to slice off sections as thin as possible. Some little practice will be necessary before they can be successfully cut of the requisite thinness.

This operation is rendered easier by the use of a section cutting table. This little piece of apparatus consists of a plate of brass, the surface of which has been turned perfectly plane; in the centre is fixed a tube containing a piston, which may be raised by means of a screw. The object whose section it is wished to procure is first cast into a block of either cocoa butter or solid paraffin. In either case the temperature of these must only just be raised to the melting point. This block of solid paraffin or other substance is next trimmed down so as to go into the tube of the section cutting table. Adjust the screw at the bottom so that the grain is in about the right position, then draw the razor across the top of the tube and cut off the upper part of the grain; screw up the piston at the bottom of the tube very slightly, and cut off a section by again drawing the razor across the plane surface of the table. In this manner thin sections may be cut with comparative ease. Having thus obtained the sections, wash them in a little spirits of wine and transfer to a slide. If it is only wished to examine them without this being preserved, they may be mounted in a mixture of water and glycerin in equal volumes, protected with a cover slip, and at once placed under the microscope. When, however, it is wished to make a permanent mount, they may be embedded in glycerin jelly (Deane's medium). Having washed and prepared a section, and also the slip and cover, place a very little of the glycerin jelly on the slide, warm very gently, and the jelly becomes liquid. Place the section carefully in the liquid medium, taking care that it is thoroughly immersed. Remove all air bubbles, place on the cover as carefully as possible, gently squeeze out any superfluous medium, and allow to cool. The jelly will then again become solid. Clean the edge of the cover glass, and coat round with asphalt varnish.

404. The Germ.—The appearance and general characteristics of the germ itself should now be carefully studied; for this purpose use the 1-inch objective.

In Plate VI. the germ is shown very distinctly, and the whole of its parts named and indicated by reference marks. This should be carefully studied. Notice that the aleurone cells of the bran terminate at the junction of the endosperm and germ, and only the "testa" or envelope of the true seed encloses the embryo. The "plumule" is that part of the young plant which penetrates to the surface during growth, and then constitutes the growing stem and leaves of the plant. It consists of four rudimentary leaves enclosed within the plumule sheath. The radicle, or rootlet, on commencing its growth, forces its way downward into the earth. The germ constitutes about 2.0 per cent. of the whole grain, while its enclosing membrane is stated by Mège Mouriès to amount to as much as 3.0 per cent.

The nature of the other portions of the germ had best be described when dealing with their functions in connexion with the act of germination (paragraph 410).

405. Endosperm and Bran.—Attention must next be directed to the structure of the endosperm and the branny coatings by which it is enveloped. For this purpose a very thin section should be selected and then examined under the ⅛-inch objective.

The bran of wheat is divided into the outer envelopes of the grain and those of the seed proper. Following these in the order of the letters given in Fig. 27:—

a—is the outer "epidermis," or "cuticle." According to Mège Mouriès this constitutes 0.5 per cent. by weight of the whole grain.

b—is the "epicarp," and amounts to about 1.0 per cent. of the grain.

c—is the last of the outer series of the envelopes of the grain, and is known as the "endocarp." It is remarkable for the well-defined round cells of which it is composed. The endocarp amounts to 1.5 per cent. of the grain.

d—is the first of the envelopes of the seed proper; it is that to which reference has already been made as the "testa"; it has also received the name of "episperm." The colouring matter of the bran occurs principally in the episperm.

e—is a thin membrane lying underneath the testa, and enveloping the aleurone cells. This membrane and the testa together form 2 per cent. of the grain.

f—is the layer of "aleurone" cells, so called from the protein of that name which they contain. As may be seen from the figure, the cells are almost square in outline; one is at times replaced by two lesser ones, as occurs immediately above the cell *f*. Notice particularly that this layer does not envelop the germ, but only encloses the endosperm.

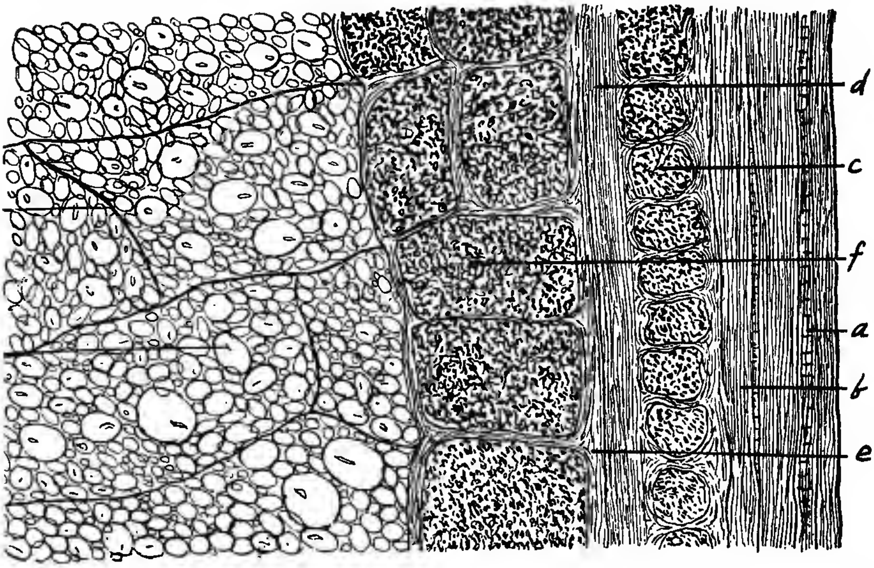


Fig. 27.—Longitudinal Section through Bran and Portion of Endosperm of Grain of Wheat, magnified 440 diameters.

g—represents the layer of parenchymatous cellulose by which the interior of the endosperm is divided up into a number of cells of comparatively large size, these in turn being filled with starch granules, and embedded in gluten.

h—shows the "hilum" of an individual starch granule.

In order to complete the investigations of the appearance, when viewed under the microscope, of the various coatings of the wheat grain, it is not only necessary to examine these skins in section, but also, so far as possible, as seen on the flat. The bran of wheat can be split up with comparative ease into three layers, which can be successively peeled off from the endosperm. The first of these consists of the epidermis, or cuticle, and also epicarp. Following these are the endocarp and episperm, which usually peel off together. The inner and last skin consists of that containing the cerealin cells.

Take a few grains of soft red wheat and soak them for a few hours in warm water; when they are sufficiently softened, take one, and with a fine pair of forceps strip off the outer skin and place it in a watch glass. When the whole of the outer skin has thus been removed, carefully strip off the middle layer in the same manner, and also reserve it for examination. The division of the inner layer from the endosperm is often only accomplished with difficulty; in case they do not separate well, let the grain soak some time longer.

Next proceed to examine these several coatings. Mount each on a slide in a drop of water (or preferably, when wished to examine the mount for some time, in a drop of glycerin), so that it is practically freed from bubbles, and lying flat and without creases. Put on a glass cover and press gently down. Examine with either a quarter or eighth-of-an-inch objective.

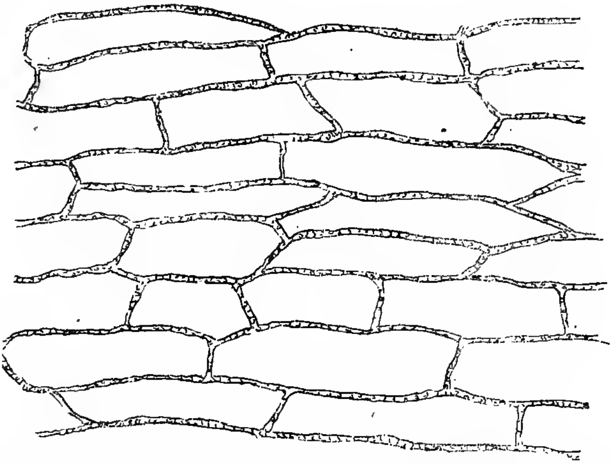


Fig. 28.—Outer Layer of the Bran of Wheat, magnified 150 diameters.

Observe in the outer layer that it consists of a series of cells, some four to six times long as broad, and arranged longitudinally in the direction of the length of the grain. A portion of the outer layer is shown in Fig. 28. Notice at the one end (of the actual section, not the figure) the beard of the grain, and note particularly the attachment of each hair to the skin (the root). Observe also the canal extending about half the length of the hair. Fig. 29 is a drawing of such hairs.

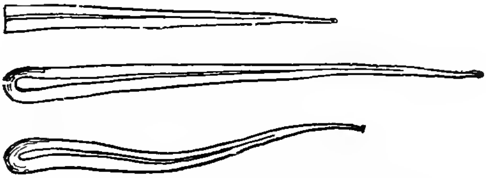


FIG. 29.—Beard of Grain of Wheat.

Next observe the appearance of the second layer of skin that has been detached; this is shown in Fig. 30.

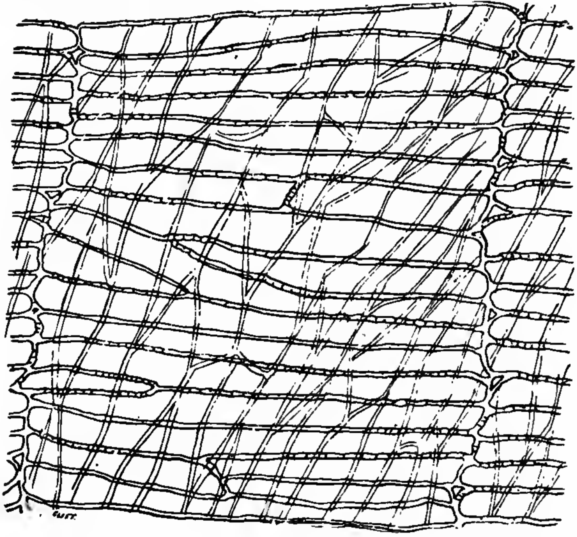


FIG. 30.—Middle Layer of the Bran of Wheat, magnified 250 diameters.

In this will be seen two layers of cells that are not both in focus at the same time, the one layer being, in fact, underneath the other. There are in the first place a series of long cells arranged transversely to the longitudinal section of bran shown in Fig. 27, where they are marked *c.*

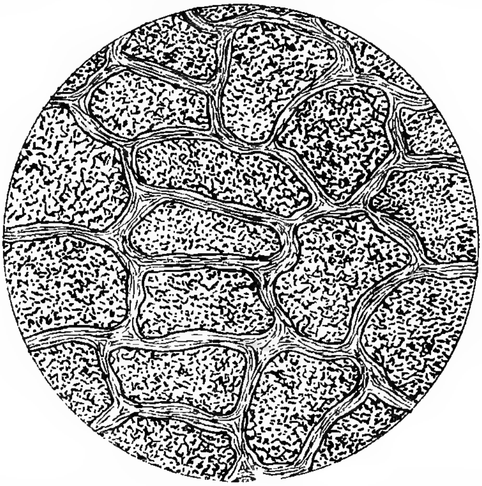


FIG. 31.—Inner or Aleurone Layer of the Bran of Wheat, magnified 440 diameters.

Because they are thus arranged around the grain of wheat they are frequently termed "girdle" cells. The great difference between looking at the same thing in one direction and then in another is strongly exemplified in this study of these particular cells in plan and in section. An instructive lesson may be gained by comparing the section illustrated in Fig. 27 with a similar section cut transversely instead of longitudinally. Such a section is given later in the series. The colour-containing cells underlie those to which reference has just been made.

In the next place examine the inner, or aleurone cell, layer of the bran. The aleurone or cerealin cells of the bran are often referred to as being cubical; that this, however, is not the fact is well shown in Fig. 31. They certainly have a square or rectangular outline when seen in section, whether longitudinal or transverse, but the skin, viewed on the flat surface, shows that the cells are irregular in outline, each accommodating its contour to that of those surrounding.

There follows a sketch of the transverse section through the bran of wheat; this should be carefully compared with the longitudinal section, Fig. 27.

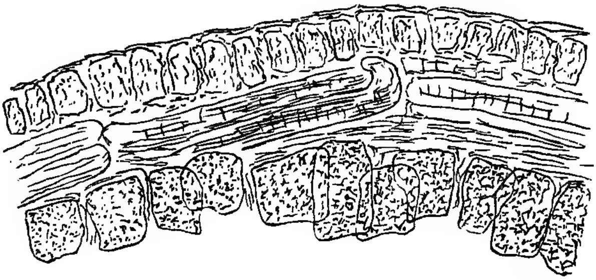


Fig. 32.—Transverse Section through Bran of Wheat, magnified 250 diameters.

The actual section from which this drawing has been made is not so good a one as the longitudinal section, from which Fig. 27 was drawn. Viewed with a moderately high power it is difficult to get very much of the thickness of the section in focus at the same time; still sufficient is noticed, on careful observation, to show the general structure of the bran. The outline of the aleurone cells is more irregular than was the case in the longitudinal section; they are also noticed to be, in several instances, overlapping each other. Looking at the cells of the middle skin of the bran, they are seen to be of considerable length, justifying the remarks made about them when studying their appearance as seen on the flat. While, however, these middle cells are seen lengthwise, it follows of necessity that the ends of the cells of the outer skin much be presented to the eye. This sketch, taken with the others, gives a tolerably complete idea of the microscopical structure of a grain of wheat.

A careful study of these sections of the wheat grain and of the various layers into which the bran can be divided should give the miller in particular a clearer and more real ideà than he can otherwise have of the nature of these outer integuments of the wheat grain, which it should be his object to remove. The study should not merely be confined to the drawings given in this work, but should extend to the actual slides themselves under the microscope.

406. Bran Cellulose.—The bran of wheat consists largely, as is well-known, of cellulose or woody fibre, together with a considerable proportion of soluble albuminous matter. Cellulose may be obtained in a fairly pure state by alternate treatment with hot dilute solutions of acid and alkali. The actual structure of the cellulose of the different layers of the bran possesses considerable interest, and may be studied in the following manner: Strip off the different layers of skin as before directed, put pieces of each in a separate test-tube, and first digest for an hour with dilute sulphuric acid; pour off the acid, and digest with caustic soda solution for another hour. Make up solutions of 1 part respectively of acid and alkali, and 20 parts of water. Wash the resulting cellulose, and mount carefully on a glass slide; examine under the microscope.

Reviewing the whole three layers, one finds that the outer one is largely composed of cellulose, and consequently is condemned as an article of human food. The middle layer contains less cellulose, but contains a higher proportion of colouring matter. The proportion of cellulose in the inner layer is still less, but the amount of protein is high. This protein body is injurious to the flour, inasmuch as it exerts considerable action on broken starch granules. There are therefore cogent reasons for the non-admission of any part of the bran into the flour.

407. Cellulose of Endosperm.—On taking a grain of wheat and carefully cutting off the bran so as to have a piece of the endosperm only, and treating this interior portion of the grain with acid and alkali, a trace of cellulose is obtained which shows no distinctive organisation under the microscope. The student will do well to verify this fact for himself. Let him also treat small quantities of different varieties of flour in a similar fashion, and examine the remaining cellulose. Such an inspection is calculated to teach much concerning the success of the operation of milling. He will be able to see whether or not the number of small particles of bran in the flour is large. He will also learn whether or not the bran itself is intact, or whether portions of one or other of the surfaces have been removed and ground up into the flour.

Physiology of Grain Life.

408. Protoplasm.—In explaining the nature of yeast, Chapter IX., reference has already been made to the fact that the interior of the cells is filled with "protoplasm," and that this material is the "ultimate form of organic matter of which the cells of plants and animals are composed." Protoplasm has also been defined as the "physical basis of life," and for that reason merits in this place some little examination. Yeast may be viewed as an unicellular plant, whereas wheat and the higher plants generally are multicellular in nature, so that yeast serves as an introduction to their study. From what has been already described of the life-history of yeast, the following conclusions as to the nature of its protoplasm may be drawn: First, that protoplasm is the seat of those chemical changes which are inseparable from the life of the organism. **Such chemical changes, collectively, are termed the metabolism of the organism.** Those processes which go to the building up of more complex chemical compounds are termed **constructive metabolic processes**, while those in which complex compounds are broken down into simpler compounds or elements are termed **destructive metabolic processes**. In the most recent nomenclature, the term metabolism is sometimes restricted to the constructive processes, while the changes of destruction or degeneration are referred to as processes of katabolism. Vines classifies the fundamental properties of the protoplasm of the yeast plant as follows:

"1. it is *absorptive*, in that it is capable of taking up into itself the substances which constitute its food.

"2. It is *metabolic,* in that it is capable of building up from the relatively simple chemical molecules of its food the complex chemical molecules of the organic substances present in the cell; and in that it is capable of decomposing the complex molecules of these substances into others of simpler composition.

"3. It is *excretory,* in that it gives off certain of the products of its destructive metabolism.

"4. It is *reproductive,* in that portions of it can become separate from the remainder, and lead an independent existence as distinct individuals."

The protoplasm of certain more highly organised unicellular plants have, in addition, other distinct properties, such as *contractibility, irritability,* etc. In the lower multicellular plants all the cells appear to be exactly alike, but in most the constituent cells vary and have special functions allotted to them: such groups or arrangements of cells constitute what is known as an *organ.* Thus, certain cells are absorptive in their nature, while others are excretory: others, again, are charged with the functions of reproduction, and these are known as the reproductory organs. The seed or grain of wheat is one of the most important among these latter, and it is only such other functions of the plant as are directly associated with seed life that can be touched on in this place.

Like other parts of plants, the seed is built up of parenchymatous cells containing modified protoplasm, which consists of a series of meshes or network enclosing within them, in the ripe seed, grains of starch. The network portion is composed of proteins, and of these an exhaustive description has already been given. The insoluble proteins constitute what Reinke named the *plastin* of the cell, while the more soluble portions are the *globulins* and *peptones;* of which latter, seeds usually contain considerable quantities. The plastin is probably the organised protoplasm of the cell, while the globulins and peptones are unorganised or dead protoplasm. The higher plants, such as the cereals, contain in certain of their cells differentiated protoplasmic bodies, which may contain colouring matter, in which case they are known as *chlorophyll-* or *etiolin-corpuscles;* or they may be colourless, in which case they are *starch-forming corpuscles* or *amyloplasts.*

409. Constructive Metabolism of Plants.—The roots serve as the absorbing medium through which the plant obtains water and substances which may be in solution in water. From the atmosphere plants absorb carbon dioxide. Much of the oxygen of this carbon dioxide is returned to the atmosphere in the free state, the carbon being used in the constructive metabolism of the plant. In addition to the carbon dioxide and water, the plant has at its disposal for metabolic purposes salts containing nitrogen and sulphur.

A most important point in the study of metabolism is that the assimilation of carbon from carbon dioxide is confined to those portions of plants which contain green colouring matter (or closely allied matter to be subsequently described). Further, the decomposition of carbon dioxide can only take place in the presence of light. On treating green leaves of plants with alcohol, the green colouring matter is dissolved out, and has received the name of *chlorophyll.* Within the leaves this chlorophyll exists in cells or corpuscles known as chlorophyll-corpuscles, the chlorophyll itself having apparently a similar composition to other protoplasm. Etiolated plants—that is, plants grown in the absence of light—contain corpuscles in which the colouring matter is yellow, not green; this matter has received the name of *etiolin,* and is doubtless closely allied to chlorophyll in properties. On exposure to light, the etiolin corpuscles absorb carbon dioxide and exhale oxygen, the etiolin being converted into chlorophyll. Investigation of a most careful and exhaustive nature demonstrates that the **absorption of carbon dioxide and exhalation of oxygen, with the formation de novo of organic matter in plants, is essentially a function of chlorophyll (including etiolin), and cannot occur in its absence.**

But little can be stated positively as to the exact nature of the chemical changes induced by chlorophyll, but they may be summed up in the statement that it produces, by synthesis, protein matter. The first step is probably the formation, from carbon, hydrogen, and oxygen, of comparatively simple substances, such, perhaps, as formic aldehyde, CH_2O (the simplest possible carbohydrate), and its polymers. (Glucose and other of the higher carbohydrates may be viewed as polymers of formic aldehyde, thus $6CH_2O = C_6H_{12}O_6$, glucose.) The next upward step might be the production of nitrogenous substances of the amide type (asparagin, etc.), and finally, by further synthesis, the still more complex protein. Differences of opinions exist as to the manner in which starch is formed by the plant—there is first the observed fact that the chlorophyll-corpuscles of a growing plant exposed to light contain starch grains, and that these disappear during darkness. Vines is of opinion that "the starch which makes its appearance in the chlorophyll-corpuscles, when constructive metabolism is in active operation, is not the first product of the synthetic processes, but only an indirect product: protoplasm is the substance which is formed in the chlorophyll-corpuscles, and it is only in consequence of the decomposition of the protoplasm formed that starch is produced." In a paper contributed to the *Journal of the Chemical Society,* in 1893, by Brown and Morris, these chemists advance the view that cane sugar is first formed as an up-grade product of constructive metabolism, and that the starch is formed within the chlorophyll-corpuscles from this compound. There is proof that protein matter is capable of being so decomposed as to result in the splitting off of a carbohydrate molecule from its substance, as in the production, for example, of the cellulose cell-wall of yeast from its protoplasm.[1] On the other hand, Brown and Morris have shown that the chloroplasts of the leaf can form starch when fed directly with cane-sugar solution, and claim that "both under the natural conditions of assimilation and the artificial conditions of nutrition with sugar solutions, the chloro-plasts form their included starch from antecedent sugar." However, in whatever manner formed, chlorophyll causes, in the presence of light, the production both of proteins and carbohydrates, including starch, within the leaf. The final process of constructive metabolism is the conversion of dead protein matter into living organised protoplasm; but our knowledge of the difference between these is very slight. Vines points out "that the primordial utricle of dead cells readily allows of the passage into it and through it of substances which could not enter or pass through it in life. This is in accordance with the well-known fact that it is impossible to stain living protoplasm; it is when protoplasm is dead that colouring matters can penetrate into it."

Having traced the synthesis of protoplasm and other organic matter in the leaf, the next problem is the mode of their translocation or transference to other parts of the plant. Brown and Morris have proved the

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[1] Pavy, in some investigations of the chemical pathology of diabetes, shows that glucose may be formed from proteins during human digestion.

existence in leaves of a diastase, which they term leaf diastase, or "translocation diastase," from its functions as an agent in the translocation of the chlorophyll products. They show that by the agency of this diastase the starch (which during darkness disappears from the chlorophyll corpuscles of the leaves) is converted into maltose. They further are of opinion that the cane-sugar which the leaves may contain is converted into dextrose and lævulose. Probably also the proteins are changed by analogous processes into peptones, and from these into amides, in which form the nitrogenous organic substances are most likely distributed through the plant. The diastase and proteolytic enzymes, then, pour into the various vessels of the plant a solution of maltose, dextrose, lævulose, and peptones and amides. These are carried to the new parts of plants for the purpose of forming buds, roots, etc., and to the seed portion, there to be stored up as provision for the young plant during its first stages of growth, and before able to obtain nutriment by the action of its own chlorophyll.

The physical structure of the wheat seed or grain has been already described, the embryo of the plant being at the lower end, near where the seed is attached to the ear, and the upper portion being the endosperm, the whole being enclosed within the cuticle known as bran. Of the formation of the seed as the plant grows, we cannot here speak; but assuming the seed to have formed its outer envelope, it before ripening is found, on examination, to be full of a milky looking fluid, which consists of the sap which is being supplied by the vessels of the plant.

Within the seed a synthetical process proceeds, by which is caused the formation of protein matter from the sugar and amides supplied by the sap. From this is derived the starch of starchy seeds, while the residuum of the protein forms what are known as *aleurone-grains.* Vines points out that comparatively little is known of the manner in which starch is formed in seeds, but it is assumed that it is produced in the same way as in other parts of the plant.

After the separation of the starch, there remains behind in the seed a small proportion of sugar; part of which consists of sucrose, and is probably an up-grade sugar, and the remainder of glucose or allied sugar produced by the subsequent degradation of the cane sugar. In some seeds the non-nitrogenous matter is stored up as oil instead of starch—comparatively little fatty matter is present, however, in wheat, except in the embryo itself.

The residual matter of the protoplasm, after the separation of starch, is stored up in the form of small granules, known as *aleurone-grains.* These form the matrix in which the starch grains are embedded, and constitute the protein matter of the endosperm. The series of cuboidal cells forming the interior layer of the bran are also filled with aleurone, and have the name *aleurone-layer.*

During the growth of the seed from the milky stage before referred to, the sap continues to bring supplies of maltose and nitrogenous matters, which undergo the constructive metabolic process just described; while under the influence of a ripening sun the water is evaporated. Gradually the contents of the seed acquire a firmer consistency, until at last the solid ripened grain of wheat is produced. In this condition the seed is in a resting stage, and may without injury be subjected to desiccation and extremes of temperature, which would be fatal were it in its active state. Under the influence of moisture and warmth, active changes are set up in the resting seed, and the development of the new plant commences.

410. Germination of Wheat and Barley.—In order to understand the phenomena of germination, reference should at this stage be made to the section of the wheat germ given in Plate VI. Although in the resting stage the wheat germ contains no starch, yet within twenty-four hours of the seed being kept in a moist state, starch is found in abundance within the germ, although no alteration has occurred in the endosperm, being doubtless produced by dissociation of the protoplasm of the embryo. This is followed by an elongation of the radicle, which at this stage contains starch, as do also the leaves of the plumule. The plumule, with its further growth, first bursts through the envelope, and finds itself in contact with the "pericarp," or outer skin of the grain (enveloping the testa). The pericarp is next ruptured, and the growth of the plumule proceeds outside the grain. On looking at the figure of the germ (or, still better, an actual section under the microscope), there will be noticed a series of elongated cells, constituting what is known as the *scutellum*: between this and the endosperm is a series of cells of another type, arranged with their longest diameters directed toward the endosperm; these latter form what is called the absorptive and secretive *epithelium*. At the time when the radicle breaks through its sheath, the cells of the scutellum lying next the epithelium begin to show starch granules, which gradually pervade the tissue of the germ: these may be taken as the first indication of the passage of reserve material from the endosperm to the germ, while the epithelium is regarded as the absorptive contrivance by which the germ thus derives sustenance from the endosperm. The first visible effect on the endosperm is the breaking down of the parenchymatous cell-walls, and following on this we have the starch corpuscles attacked. There are, in the first place, minute pittings on the surface of the grains of starch, which increase both in size and number until the whole granule is completely dissolved, with the formation of maltose. The dissolution and assimilation of the starch of the endosperm proceeds gradually, the more remote parts being last to suffer attack. The protein matter of the endosperm is at the same time converted into peptone, and probably amides, by a proteolytic enzyme. By means of the epithelium, these are transferred to the growing plant. The aleurone cells of the bran show no signs of change until the reserve starch is nearly exhausted, when they begin to suffer attack, the cell-walls undergoing dissolution. Doubtless the function of the aleurone cells is to provide protein nutriment for the plant at a comparatively late stage of its growth, hence the highly resistant cell-walls. In their researches on the *Germination of the Gramineæ*, Brown and Morris demonstrate that the epithelium of the germ secretes diastase during germination, and this is the agent of transformation of the contents of the endosperm. They also, as has been previously mentioned, have shown that the diastase of germinating grain is *cyto-hydrolytic* (cellulose dissolving) as well as *amylo-hydrolytic*. They consider the former action to be due to a distinct and separate enzyme from diastase proper, and that it also is secreted by the epithelium.

Two varieties of diastase have been described in the chapter on Enzymes, that from raw grain, and ordinary or malt diastase—the former is probably identical with the diastase of translocation, by which the starch of the chloroplasts is converted into sugar; while the latter is essentially a diastase of germination, and is only secreted by the epithelium of the scutellum. The power to liquefy starch-paste and to erode starch-granules always accompany each other, and, in fact, are never separable, being in each case functions of germination diastase, or *diastase of secretion*. Raw grain diastase is produced during the production of the embryo in the growing and unripe seed, and probably then acts as translocation diastase for the purpose of preparing nutritive matter for the developing embryo. The portion of such diastase remaining unused in the ripe seed constitutes the diastase of raw or ungerminated grain.

The changes just described are those which wheat undergoes during germination, and occur in an incipient form in sprouted or "growy" wheat, in which the diastase of secretion, together with cytase, will have more or less broken down the parenchymatous cell-walls, and also possibly have eroded some of the starch. A useful test for growy wheat is to examine the germ for starch; if any such granules are found within a section when viewed under the microscope, it may safely be concluded that the wheat is unsound. The changes to which malt owes its properties are practically the same; when germination has proceeded sufficiently far, its further course is arrested in malting by kiln-drying the grain.

Experimental Work.

411. The experimental work undertaken in connexion with the subject-matter of this chapter should consist in following its detailed directions for microscopic examination of wheat.

CHAPTER XIV.

CHEMICAL COMPOSITION OF WHEAT.

412. Principal Constituents of Cereals.—Proximate analysis of the cereal grains shows that they contain as their principal constituents—fat, starch, cellulose, dextrin, sucrose, raffinose, and possibly other sugars; soluble protein bodies, consisting of albumin, globulin, and proteose; insoluble protein bodies, consisting of glutenin and gliadin, which together constitute gluten; mineral matters, consisting principally of potassium phosphate and water.

In a table recently compiled by Hutchison, the general composition of the cereals is given as follows:—

Constituents.	Wheat.	Barley.	Oats, Hulled.	Maize.	Rye.	Rice, no Husk.	Millet.	Buckwheat.
Fat	1.7	1.9	8.1	5.4	2.3	2.0	3.9	2.2
Carbohydrates..	71.2	69.5	68.6	68.9	72.3	76.8	68.3	61.3
Cellulose ..	2.2	3.8	1.3	2.0	2.1	1.0	2.9	11.1
Proteins ..	11.0	10.1	13.0	9.7	10.2	7.2	10.4	10.2
Mineral matter	1.9	2.4	2.1	1.5	2.1	1.0	2.2	2.2
Water	12.0	12.3	6.9	12.5	11.0	12.0	12.3	13.0

413. Average Composition of American Wheats.—Herewith is given the average composition of American wheats, according to Richardson, Chemist to the United States Department of Agriculture. The carbohydrates consist of the starch, dextrin, and sugar. The total quantities of proteins are given, being derived from the percentage of nitrogen found.

AVERAGE COMPOSITION OF AMERICAN WHEATS.

No. of Analyses.	District where grown.	Weight of 100 grains.	Water.	Ash.	Oil.	Carbo-hydrates.	Cellulose.	Proteins.	Nitrogen.	Heaviest 100 grains.	Lightest 100 grains.	Highest Proteins.	Lowest Proteins.
		Grams.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Grams.	Grams.	Per cent.	Per cent.
260	United States and Canada	3.638	10.27	1.84	2.16	71.98	1.80	11.95	1.91	5.924	1.830	17.15	8.05
108	Atlantic and Gulf States	3.464	10.42	1.75	2.17	72.61	1.72	11.33	1.81	5.079	1.830	15.58	9.45
47	The Middle West . . .	3.607	10.51	1.76	2.01	71.67	1.90	12.15	1.94	4.902	2.138	16.63	10.15
97	West of the Mississippi . .	3.806	10.04	1.99	2.22	71.12	1.87	12.76	2.04	5.924	2.561	17.15	10.15
8	The Pacific Coast	5.044	9.74	1.84	2.08	76.18	1.56	8.60	1.37	(5.745)	(4.253)	9.47	8.05
6	Canada	3.325	9.74	1.56	2.29	73.87	1.67	10.87	1.74	3.686	2.964	14.70	9.45
32	Pennsylvania . . .	3.373	10.72	1.67	2.05	72.45	1.73	11.38	1.82	4.658	2.035	15.58	9.45
9	Maryland	3.597	10.52	1.75	2.09	72.25	1.74	11.65	1.86	5.079	3.075	14.53	9.80
11	Virginia	3.343	10.34	1.70	2.21	71.87	1.71	12.71	1.95	4.208	1.830	14.00	10.15
7	Georgia	3.597	10.00	1.96	2.30	72.24	1.72	11.78	1.89	4.627	2.834	14.00	9.45
22	North Carolina	3.776	10.03	1.59	2.25	73.94	1.76	10.43	1.67	4.628	2.780	12.43	8.93
17	Alabama	3.314	10.94	2.03	2.21	71.84	1.62	11.36	1.79	4.647	2.011	13.65	9.80
—	Michigan (Kedzie) . .	—	11.28	1.73	—	74.97	—	12.02	1.92	—	—	13.78	9.13
22	Michigan	3.969	10.71	1.64	2.06	72.12	1.80	11.67	1.87	4.902	3.402	15.23	10.50
8	Kentucky	3.454	10.83	1.75	1.87	70.37	2.03	13.15	2.10	3.666	3.146	14.53	11.90
14	Tennessee	3.150	10.19	1.89	2.00	71.33	2.02	12.51	2.00	3.990	2.138	16.63	10.15
12	Missouri	3.502	9.80	1.92	2.19	72.36	2.17	11.56	1.86	3.867	3.098	14.00	10.50
9	Minnesota	3.354	10.60	1.71	2.03	70.96	2.04	12.66	2.03	3.828	3.116	17.15	10.85
10	Kansas	3.204	11.80	1.64	1.98	71.35	2.08	11.15	1.78	3.424	2.881	12.25	13.50
19	Texas	2.847	10.03	1.81	2.11	70.85	2.06	13.14	2.10	3.937	2.561	15.23	10.68
45	Colorado	4.682	9.57	2.21	2.38	70.91	1.62	13.31	2.13	5.924	3.851	15.94	11.19
8	Oregon	5.044	9.74	1.84	2.08	76.18	1.56	8.60	1.37	5.745	4.253	9.47	8.05

414. Composition of Wheats, Fleurent.—Fleurent gives the following as the composition of certain hard wheats examined by him, viz., Russian, Algerian, and Canadian wheat. (The last, however, contained from 25 to 30 per cent. of soft wheat.) The relative weight of endosperm, embryo, and husk, is of interest:—

	Russian Wheat.	Algerian Wheat.	Canadian Goose Wheat.
Average weight of a grain in grams	0.030	0.048	0.037
Constitution, per cent:—			
Endosperm	84.95	84.99	84.94
Embryo	2.00	1.50	2.05
Husk	13.05	13.51	13.01

COMPOSITION OF THE ENTIRE WHEAT.

Water	11.42	11.34	11.36
Nitrogenous matters:—			
Gluten	14.76	11.00	10.88
Soluble (Diastases, etc.) ..	2.25	1.82	1.67
Ligneous, of husk	1.92	1.90	1.91
Starch	50.15	55.05	54.55
Fatty Matters	1.18	1.93	2.70
Soluble Carbohydrates:—			
Sugars	2.14	2.68	2.18
Galactose	0.65	0.46	0.75
Of husk	1.76	2.19	1.90
Cellulose	9.73	9.40	9.21
Mineral Matters	1.56	1.42	1.35
Undetermined and loss	2.48	0.81	1.54
	100.00	100.00	100.00

The gluten of the Russian wheat was found to contain: gliadin, 46.45; glutenin, 37.89; congluten, 15.66 per cent. To the congluten, Fleurent ascribes the tenacity and want of elasticity of the flour of these hard wheats, which make inferior bread (*Comptes Rend.* 133, 944).

415. Durum Wheat, Norton.—This variety of wheat, *Triticum durum*, is largely grown near the Mediterranean, and in Southern Russia, for the manufacture of macaroni. Of recent years it has been somewhat extensively grown in America, and used in the manufacture of bread flours. In consequence, durum wheat has attracted considerable attention, not only in America, but also from European importers of American flours. An extensive investigation of its properties was carried out at the South Dakota Agricultural Experiment Station, U. S. A., by Norton, with the following results. Samples of the wheat were grown at the station and compared with European durum wheat, and also other American varieties of wheat.

The Grain. The durum wheats have a very large kernel, being nearly twice as large as that of ordinary bread wheats. The grains are hard, of an amber colour, and appear almost translucent.

Composition of the Wheat. In order to compare the general composition of durum wheats with the bread wheats, a proximate analysis of Kubanka, one of the best Russian durum wheats, and one of the best American bread wheats (Blue Stem, Minnesota), was made. The results of these analyses, together with the mean of American wheats as published by the Bureau of Chemistry of the Department of Agriculture, U. S. A., are given in the following table:

Constituents.	Kubanka Durum Wheat.	Minnesota Bread Wheat.	Mean of American Wheats.
Water	9.32	6.00	10.62
Mineral Matter	1.71	2.46	1.82
Fat	2.34	2.49	1.77
Crude Fibre	2.52	3.35	2.36
Crude Protein, N × 5.7	14.46	13.21	12.23
Carbohydrates other than Crude Fibre	69.65	72.49	71.18
Sugar	3.26	1.42	—
Dextrin	1.25	—	—
Invert Sugar, Soluble Starch	Nil	Nil	—

This wheat was found to be remarkably sweet, and hence the sugar was determined with, as shown, a very high percentage. The dextrin is also extremely high as compared with quoted analyses by Stone, in which 0.27 and 0.41 per cent. respectively of dextrin were found in whole wheats. In the case of the flours, as a result of indirect indications, macaroni or durum flours are estimated to contain from 1 to 2 per cent. of sucrose as against 0.18 and 0.20 per cent. in two samples analysed by Stone.

Protein Content of American Crops. In American durum wheat crops, there is an increase in protein matter as against original imported seed. The following are some results calculated to the water-free basis:—

	Number of Analyses.	Protein, N × 5.7 Per Cent.
Imported seed	7	15.73
Crop of 1901	31	18.13
„ 1902	32	14.57
„ 1903	45	17.34

The year 1902 was a very unfavourable one for durum wheat.

Durum Flour. A straight flour was prepared from durum wheats, apparently of the 1903 crop, and various determinations made thereon.

Colour. The durum wheats possess a yellow colouring principle which is also found in the flour, which is in consequence of a deep yellow tint expressed on the Lovibond tintometer scale by 0.25 yellow + 0.17 orange. This colouring matter is soluble in alcohol and ether, but is insoluble in distilled water. It is somewhat readily soluble in dilute alkalies, and is discharged from solution by acids. (It is probably as a result of a similar reaction that flour is stained yellow by the addition of sodium carbonate.)

Protein.—The following are the means of a number of determinations made on durum flours:—

Crude Protein	15.00	per cent.
Wet Gluten	53.77	„
Dry „	17.68	„
Gliadin	7.87	„
„ of total Protein	47.17	„

The gliadin determinations are calculated on a water-free basis.

The durum flours have a large gluten content, but the quality is not good, usually showing very poor adhesive qualities, and but little elasticity. These are properties commonly ascribed to lack of gliadin. Though all the durum flours have high gluten and sugar contents, yet the bread from many of the poorer durum wheat flours neither rises during the fermentation nor in the oven.

Bakers' Tests. On being subjected to a baker's sponging test in which the flour is made into a sponge, allowed to ferment, and the volume read off, the volume of the best durum flours was as high as that of the bread wheat flours. In baking tests, durum flour becomes more sticky than bread wheat flours; also if the doughs are a little too stiff they do not rise properly, and the bread is heavy and of poor texture. With a sufficiency of water, the volume, weight, and texture of the best durum wheat breads compare favourably with those from the best bread wheats, and the flavour is decidedly pleasing (*Jour. Amer. Chem. Soc.*, 1905, 922).

416. Voller on Wheats.—The tables on pages 260-5, headed "Dictionary of Wheat," are taken from Voller's excellent work on "Modern Flour Milling." They are particularly valuable as a succinct record of the milling and baking characteristics of the most important wheats and their flours of the world's supply. Mr. Voller has very kindly made specially for this work a number of corrections and additions to these tables.

Voller also gives some useful rules as to selection of wheats for different characters, and also a table of mixtures equivalent to certain single wheats, which may be used to replace the latter on their becoming exhausted. Thus—

For largest loaf, *use* good Minnesota or Manitoba, run very close by fine Saxonska, Azima or Ghirka.
For whitest flour, *use* good White English, Oregon, Australian, or Ros Fe Plate, with choice for the latter.
For sweetest bread, *use* good English and Manitoban in about equal parts.

The following are examples of replacing mixtures, but are not intended as exact equivalents in any sense:—*

Single Wheats.	May be replaced by
2 American Spring	1 Manitoban. 1 Red Winter Kansas.
2 Red Winter American	1 Bahia Plate. 1 Ros Fe Plate.
3 Manitoban	2 Saxonska. 1 Ghirka.
1 Manitoban	1 Ghirka, Azima, or Ulka.
2 Australian	1 Californian or Walla. 1 C. W. Kurrachee.
2 California (or Walla)	1 Australian. 1 Chilian.
2 Red Winter American	1 Plate. 1 Canadian (Soft).
2 Californian or Australian	1 White Bombay. 1 Walla.
2 Mixed Indian	1 Australian. 1 Bahia.
2 Bar-Russo Plate	1 Manitoban. 1 Calcutta, No. 2, or Red Kurrachee.

417. Chemical Changes during the Formation and Ripening of the Wheat Grain, Teller.—The following experiments were made in Arkansas, U. S. A., 1897. Half an acre of growing grain was purchased

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*The best substitutes for English sorts are the following:—Soft Canadians, and Winter Americans, Dantzic, German, French and Mild Plates.

early in May, and on the 22nd instant, when the wheat was past blossoming, and the grain was set, a portion was cut. A further portion was cut on each successive day, till forty-two portions in all were obtained. The portions ranged in weight from 80-90 pounds at the commencement to about 50 pounds at the close of the series. Immediately on cutting they were carefully air-dried, and then stored in bundles till threshing time. The summer was unusually dry. The wheat was threshed and cleaned at the end of September. Analyses were then made on samples which were hand-picked to free them from all foreign matter.

For various reasons the forty-two samples were arranged in fourteen groups of three each. The following table shows the—

STAGE OF DEVELOPMENT OF WHEAT WHEN CUT.

Roman numerals indicate number of the group of three cuttings each. Figures in parenthesis indicate numbers of the cuttings.

I.	(1, 2, 3)	A little past blossom. Grain set.
II.	(4, 5, 6)	Berries one-half to full length of ripe grain.
III.	(7, 8, 9)	Crushed berries exude a thin milky liquid. Lower leaves beginning to die.
IV.	(10, 11, 12)	Grain well in milk.
V.	(13, 14, 15)	Heads and kernels well developed. Interior of the grain a thin dough.
VI.	(16, 17, 18)	Grain in dough.
VII.	(19, 20, 21)	Grain in stiff dough. Straw becoming yellow at butt. Grain shells a little with rough handling.
VIII.	(22, 23, 24)	Straw in field much yellowed but still decidedly green.
IX.	(25, 26, 27)	Grain oozes a thin liquid when crushed between the thumb nails. Contents still slightly viscid. Straw still a little green.
X.	(28, 29, 30)	Wheat fit to cut at beginning of this period. Straw has lost all its green colour and is dark purple immediately below the heads. Berry nearly dry. May be crushed between the thumb nails but without contents adhering to them.
XI.	(31, 32, 33)	More than ripe. Straw bright and stands up well.
XII.	(34, 35, 36)	” ” ” ” ”
XIII.	(37, 38, 39)	” ” ” ” ”
XIV.	(40, 41, 42)	” ” ” ” ”

The wheat was of the variety known as the Fulcaster. It is a red, bearded, wheat which is extensively grown in Arkansas.

DICTIONARY OF WHEAT (FOREIGN

Wheat.			Quality of Bread.			Yield of Flour.	Weight of Wheat per Bushel.
Sort.	Colour.	Structure	Taste.	Strength.	Colour.		
AMERICA (UNITED STATES).							
Michigan........	White	Soft or mild	Sweet	Moderate	Good	68-72	60-63
Oregon	White	Mild	Dry insipid	Low	Fine	70-74	61-63
Blue Stem	White	Mild, dry	“	“	“	70-74	61-63
Walla Walla.....	White	Dry to brittle	Poor, insipid	“	Fair to good	68-71	60-62
Californian.	White	“	“	“	Good to fine	68-72	60-63
Goose or Durum Wheat.........	Yellow	Very hard	Dry, coarse	“	Low to fair	62-66	60-62
CANADIAN (Soft)..........	White	Mild, soft	Sweet	Fair	Good to fine	68-72	60-63
CHILIAN.......	W or M	Dry to hard	Insipid	Low	“	68-73	60-64
ARGENTINE.							
Plate—Candeal..	Yellow	Hard, flinty	Coarse	Fair to good	Poor to fair	62-66	60-64
“ Saldome...	Yellow	“	“	“	“	62-66	60-64
OCEANIA.							
Australian — Victorian & N.S.W.	White	Soft to dry	Sweet	Fair	Good to fine	70-74	61-64
South and West Australian.....	White	“	“	“	“	70-74	61-64
New Zealand....	White	Soft, mild	“	Low to fair	Fine	70-73	61-64
INDIA.							
Bombay (Soft)...	White	Mild, dry, or brittle	Strong	Fair to good	Good to fine	70-73	62-64
Delhi............	White	“ “	“	“	“	70-73	62-64
Kurrachee.......	W or M	“ “	“	“	Fair to good	66-70	60-64
Calcutta.........	W or M	“ “	“	“	“	66-70	60-64
GERMANY.							
Dantzic..........	White	Soft, mild	Sweet	Fair	Good to fine	68-71	60-63
Konigsberg......	White	“	“	“	“	68-71	60-63
Rostock..........	White	“	“	“	“	68-71	60-63
RUSSIA.							
Taganrog Cones..	Yellow	Hard, flinty	Dry, coarse	Low	Low to fair	62-66	60-63
Kubanka Cones..	Yellow	“	Good or sweet	Good	Fair to good	64-70	60-63
EGYPTIAN.....	White or mixed	Mild to hard	Dry, coarse	Low	Low to fair	64-72	58-62
ENGLAND.							
Talavera.........	White	Mild, soft	Sweet	Low to fair	Good to fine	68-72	60-64
Chidham........	White	“	“	“	“	68-72	60-64
Rough Chaff.....	White	“	“	“	“	68-71	60-64
Webb's Challenge	White	“	“	“	“	68-71	60-64
Hallett's Victoria	White	“	“	“	“	68-71	60-64
Salvator.........	White	“	“	“	“	67-70	60-63
Essex White.....	White	“	“	“	“	68-71	60-64

WHITES AND ENGLISH).

Impurities Present.			General Remarks.
Regular.	Occasional.	Probable %	
Chaff, screening, seeds, maize	Dirt, oats, barley	1-3	Clean, good wheat. Satisfactory substitute for English.
Chaff, oats, barley, seeds	Smut, stone	1-3	Fine handsome grain. Low cleaning loss. High flour yield.
" " "	Smut, dirt, stone	1-3	" " " " "
Chaff, smut, oats, barley, seeds	Dirt, stone	1-4	Yellow tint to flour. Fair quality as 2nd class white wheat.
Short straws, smut, seeds, screen'gs	Oats, barley, stone, scented seeds	1-5	Invaluable mixing sort. Useful all-round white.
Maize, chaff, screenings	Peas, oats, barley, dirt	1-4	Low flour yield. Washing alone can tone its hardness. Difficult to finish.
" " "	" " "	1-5	A good coloury wheat of mild character.
Stone, dirt, seeds, chaff	Oats and barley	2-6	Variable quality. Well worked mills a dead white flour. Very fine in grain.
Oats, barley, seeds	Dirt, smut	2-6	Needs careful washing and milling. Not good flouring wheat.
" " "	" "	2-6	" " " " "
Chaff, screenings	Oats, barley, seeds	1-3	Choice colour wheat. Valuable with reds as mixing.
" "	" " "	1-3	" " " " "
" "	" " "	1-3	" " " " "
Stones, dirt, gram, seeds	Oats, barley	3-6	Variable. Often fine quality, but purchases need close watching. Indians all need wash'g.
" " "	" "	3-6	" " " " "
" " "	" "	3-6	Useful blending sorts. Absorb water freely. Fair colour.
" " "	—	3-6	" " " " "
Chaff, screenings, dirt	Oats, barley, smut	2-5	Excellent mild working colour wheat.
" " "	" " "	2-5	" " " "
" " "	" " "	2-5	" " " "
Oats, barley, seeds, rye	Smut, dirt, stone	2-6	Very hard to mill. Low in flour yield.
" " "	" " "	1-5	Strong hard grain. Washes to advantage.
Dirt, stone, seeds, barley	Peas, beans	3-8	Washing absolutely needed. Colour of flour dead white.
Chaff, screenings	Seeds, garlic, smut, dirt, vetches	1-2	Large good wheat of top quality.
" "	" " "	1-2	Brilliant handsome qual. Highest colour form.
" "	" " "	1-2	Very reliable and a general favourite.
" "	" " "	1-2	" " " " "
" "	" " "	1-2	Unexcelled for colour when well grown.
" "	" " "	1-2	Large, but hardly fine quality. Too coarse.
" "	" " "	1-2	Fine medium grain, clear skinned and white.

DICTIONARY OF WHEAT (FOREIGN

Wheat.			Quality of Bread.			Yield of Flour.	Weight of Wheat per Bushel.
Sort.	Colour.	Structure.	Taste.	Strength.	Colour.		
ENGLAND-cont.							
Red Lammas....	Red	Mild, soft	Sweet	Low to fair	Good to fine	67-70	60-64
Nursery.........	Red	“	“	“	“	67-70	60-64
Biddle's Imperial	Red	“	“	“	“	67-70	60-64
Browick.........	Red	“	“	“	Good	67-70	60-63
Square Head.....	Red	“	“	“	“	67-70	60-63
Square Head's Master........	Red	“	“	“	“	67-70	60-63
April............	Red	“	“	“	Fair to g'd	65-68	60-62
Blue Cones......	Red	Dry to hard	“	“	“	66-69	60-63
Rivetts Cones....	Red	“	“	“	“	66-70	60-63
Golden Drop.....	Red	Mild, soft	“	“	“	66-68	60-63
Prolific..........	Red	“	“	“	Good	67-70	60-64
Windsor Forest..	Red	“	“	“	“	67-70	60-64
FIFE (new type).	Red	Firm to Hard	“	Good	“	68-72	60-66
SCOTCH........	R, or W	“	“	Low	“	67-70	60-63
IRISH...........	R or W	“	“	“	“	67-70	60-63

DICTIONARY OF WHEAT

Wheat.			Quality of Bread.			Yield of Flour.	Weight of Wheat per Bushel.
Sort.	Colour.	Structure.	Taste.	Strength.	Colour.		
AMERICA (U. S.)							
No. 1 Hard Spring	Red	Hard	Sweet	Full	Good	70-72	60-65
No. 1 Northern “	Red	“	“	“	“	68-71	58-64
No. 2 “ “	Red	“	“	Good to full	“	67-70	57-63
No. 2 Chicago “	Red	“	“	Good	“	67-70	57-62
No. 3 Spring “	Red	“	“	Fair to good	Fair	62-66	56-60
No. 1 Red Winter (Choice)	Red	Mild, dry	“	Fair	Good to choice	70-73	60-64
No. 2 Red Winter	Red	“	“	“	Good	68-72	58-62
Kansas Winter (Hard)	Red	Hard	“	“	Fair to good	67-71	58-62
Western Winter..	Red	Mild or hard	“	“	“	66-70	57-61
CANADIAN.							
No. 1 MANITOBAN	Red	Hard	“	Good to full	Good	70-73	60-65
No. 2 “	Red	“	“	Good	“	68-71	58-64
No. 3 “	“	“	“	“	“	68-70	58-62

WHITES AND ENGLISH)—*continued.*

Impurities Present.			General Remarks.
Regular.	Occasional.	Probable %	
Chaff, Screenings, vetches	Smut,garlic,seeds, dirt	1-3	Safe old-fashioned sort. Works very white.
“ “ “	“ “ “	1-3	Small regular grain. Excellent quality.
“ “ “	“ “ “	1-3	“ “ “ “ “
“ “ “	“ “ “	1-3	Large bright red wheat. Average working sort.
“ “ “	“ “ “	1-3	“ “ “ “ “
“ “ “	“ “ “	1-3	“ “ “ “ “
“ “ “	“ “ “	1-3	Thin grain. Not of highest milling quality.
“ “ “	“ “ “	1-3	In good repute for fine taste and colour.
“ “ “	“ “ “	1-3	Makes weak, coarse grained flour of dead white colour.
“ “ “	“ “ “	1-3	Rather a low class among the native reds.
“ “ “	“ “ “	1-3	Good standard quality. Liked by millers.
“ “ “	“ “ “	1-3	“ “ “ “
“ “ “	Seeds and dirt	1-2	Valuable type grown from Manitoban seed.
“ “ “	“ “ “	1-3	Like much of the English, rather too soft and weak.
“ “ “	“ “ “	1-3	“ “ “ “ “

(FOREIGN REDS).

Impurities Present.			General Remarks.
Regular.	Occasional.	Probable %	
Cockle,seeds,spelt, white oats,chaff, maize	Peas, barley smut, stone	1-3	The premier strong wheat. Reliable for grade and working quality.
“ “ “	“ “ “	1-3	Nearly equal to No. I. Hard for strength. In good repute amongst millers.
“ “ “	“ “ “	2-5	Less reliable than No. I of same class. Thinner, with more waste.
“ “ “	“ “ “	2-5	A safe grade of moderate strength. Small bright wheat.
“ “ “	“ “ “	3-8	Must be handled with caution as being distinctly a risky grade.
Cockle, grassseeds, oats, maize	Peas, seeds, garlic, stone, barley	1-3	Should be long berried of brilliant quality. Works mild and white.
“ “ “	Stone, garlic, peas, barley	2-4	A safe and favourite grade. Dry and mild, without great strength.
“ “ “	Stone, peas, barley	2-4	Usually clean and regular. Of hard ricey structure. Moderate strength.
“ “ “	Smut, peas, barley	2-5	An off grade—not invariably regular in quality
Cockle&seeds,spelt, white oats,maize	Peas, dirt, stone, barley	1-3	Fine handsome as grain. Larger, but hardly as strong as Duluth I.
“ “ “	“ “ “	2-4	Good as a substitute for I. Northern Spring, though a trifle weaker.
“ “ “	“ “ “	2-4	Useful as a cheaper substitute for No.2 grade.

DICTIONARY OF WHEAT

Wheat.			Quality of Bread.			Yield of Flour.	Weight of Wheat per Bushel.
Sort.	Colour.	Structure.	Taste.	Strength.	Colour.		
CANADIAN-cont.							
No. 4 MANITOB. (Sometimes Frosted)	Red	Hard	Variable	Low to fair	Fair	62-65	56-60
Canadian (Soft)..	Red	Soft or mild, dry	Sweet	Fair	Good	70-72	60-62
RUSSIAN.							
Choice Azima....	Red	Hard or med. hard	Dry, strong	Good to full	Good	68-72	60-65
“ Ghirka.....	Red	“ “	“	Good	“	68-72	60-65
Azima, 2nd qual..	Red	“ “	“	Fair to good	Fair to good	64-68	58-62
Ghirka “ “	Red	“ “	“	“	“	64-68	58-62
Azima or Ghirka, third quality	Red	Soft or med. hard	“	Fair	Low, uncertain	60-65	55-60
Saxonska........	Red	Dry, hard	Good	Good to full	Good	68-72	60-65
North Russian...	Red	“	“	“	“	68-72	60-65
Polish...........	Red	Med., hard, or mild	Sweet	Fair to good	“	66-71	60-62
Siberian.........	Red	Medium	Dry, strong	“	Fair	65-70	56-60
Ulka.............	Red	Mild to Hard	Good	Good	Good	66-72	60-64
TURKEY.							
Danubian, first quality	Red	Hard or flinty	Dry	Low, fair to good	Fair to good	68-72	60-64
Danubian, second quality	Red	Med. hard to flinty	“	Low to fair	“	66-70	59-63
Salonica.........	Red	Dry to hard	“	Fair to good	“	66-70	60-63
Dede Agatch.....	Red	“	“	“	“	66-70	60-63
HUNGARIAN (Hard)	Red	Dry hard to flinty	Dry, sweet	Good to full	Good	68-72	60-64
ARGENTINE.							
ChoicePlate, No. 1 Barletta (RosFe)	Red	Mild to dry hard	Sweet	Fair to good	Choice	67-70	62-64
F.A.Q. Plate, No. 2 Barletta	Red	Mild to med. hard	“	“	Good to choice	65-68	59-63
Bar-Russo (Barisco)	Red	Hard	Sweet	Fair to good	Bright	66-72	60-65
Bahia............	Red	Mild to dry hard	Sweet	Fair to good	Good to choice	67-70	60-64
CALIFORNIAN	Red	Brittle to dry hard	Dry, rough	Low	Fair to good	68-72	60-63
DANTZIC.......	Red	Soft, mild, to dry	Sweet	Fair	Good	68-71	60-63
KONIGSBERG..	Red	“ “	“	“	“	68-71	60-63
INDIAN, No. 1 (Hard Delhi)	Red	Hard to flinty	Dry, ricey	Fair to good	Fair to good	68-72	62-65
“ No. 1 (Soft).	Red	Mild-dry hard	Dry	“	“	66-70	61-64
“ No. 2 (Mxd.)	Red	“ “	“	“	“	66-70	60-63
SAMSOON (Asia Minor)	Red	Dry to brittle	“	Low to fair	Low to fair	66-70	60-63
PERSIAN.......	Red	Brittle to hard	“	“	“	65-70	60-63
MANCHURIAN.	Red	Medium, hard	“	“	Fair	65-70	56-62
MOLDAVIAN...	Red	Dry to hard	Dry or sweet	Fair to good	Fair to good	68-72	60-64

Weight per bushel is for Imperial measure, and wheat supposed uncleaned as imported unless grossly mixed with coarse light refuse—then after a light screening only. The weights, flour yields, and losses in cleaning, as also the ordinary refuse contained in the different sorts, are all to be taken as the fair average

(FOREIGN REDS)—*continued.*

Impurities Present.			General Remarks.
Regular.	Occasional.	Probable %	
Smut, seeds, oats, barley	Peas, dirt, stone	3-6	The presence of frosted grain should induce caution. Low yields.
White maize, oats, seeds, peas	Dirt, stone, smut	2-4	Excellent substitute for English. Decidedly weak in baking.
Rye, seeds, dirt, screenings	Smut, barley, oats	2-3	The best all the year round wheats to fill place of American Springs.
“ “ “	“ “ “	2-3	“ “ “ “ “
“ “ “	“ “ “	3-8	More waste than in No. 1 grades, and a lower flour yield to be expected always.
“ “ “	“ “ “	3-8	“ “ “ “ “
Rye, smut, dirt, seeds	Barley, oats, stone	5-12	Excess of rye, smut, and seeds demands great care in working.
Cockle, screenings, dirt	Smut, rye, oats, barley	2-6	When available a useful change for best Ghirkas.
“ “ “	“ “ “	2-6	“ “ “ “ “
Cockle, rye, dirt, seeds	Smut, oats, barley	3-8	Somewhat softer than Azimas and Ghirkas. Often a better colour.
Rye, seeds, dirt	“ “ “	3-8	Inferior to standard grades of Russian.
“ “ “	“ “ “	3-8	Now largely used to replace Azima and Ghirka.
Tares, seeds, screenings	Smut, oats, barley	2-4	Clean bright grain. Hard usually, and requires plenty of water.
Tares, rye, smut, seeds	Dirt, oats, barley	3-8	Often difficult to clean satisfactorily owing to large tares and other seeds.
Screenings, barley, smut, dirt	Stones, rye	3-8	Not a high grade, though useful cheap mixing sort.
“ “ “	“ “	3-8	“ “ “ “ “
Seeds and screenings, dirt	Rye, oats, barley	1-4	Bright regular grain. Should be of maximum strength.
Black oats, barley, seeds	Smut, dirt	2-4	Long berried and fairly clean. Will produce very white flour.
Black oats, barley, smut, seeds	Dirt, stone	3-6	Variable as to waste and grown grain. Well cleaned will work white.
Oats, barley	Smut, seeds	2-6	Dry brittle variety very useful for replacing American Winters or Ros Fe Plates.
Black oats, barley, seeds	Smut, maize, dirt	2-5	Nearly as good quality as good Plate Barlettas
Short straws, oats, barley, seeds	Dirt, stone, scented seeds	2-5	Yields a characteristic yellow flour. As a rule very weak.
Seeds, barley, oats	Dirt, smut, rye	2-5	More akin to English in work than any other. White flour.
“ “ “	“ “ “	2-5	Generally as the Dantzic grades. Mild coloury wheat.
Dirt, stone, seeds, barley, peas	Gram, oats, spice	3-6	Often large and good grain. Requires great care in cleaning and milling.
“ “ “	“ “ “	3-6	“ “ “ “ “
“ “ “	“ “ “	5-12	Being under top grade, will call for greater care in working.
Dirt, stone, barley, seeds	Oats, peas, beans	4-12	Variable as a rule; needs extreme care in cleaning.
“ “ “	“ “ “	4-10	Must be washed well to get full value from these hard wheats.
Rye, seeds	Barley, oats	3-8	Useful to replace any secondary reds of fair strength.
Tares, seeds, rye, smut	Barley, oats, dirt	2-6	At times will mill and bake very well. Heavy sound wheats.

range. Russian samples admit of almost endless classification under names of ports—Berdiánski, Novorrossisk, Ghenighesk, Marianople, Nicolsieff, Odessa, and many others. The general types are in all these instances Azi [illegible] fore apply unless a new grade is specified.

The composition of the wheat at each stage is given in the following table:—

TABLE SHOWING THE PROXIMATE COMPOSITION OF WHEAT, IN PER CENT. OF THE TOTAL DRY MATTER, AT FOURTEEN DIFFERENT PERIODS OF THREE DAYS EACH FROM THE SETTING OF THE GRAIN TO PAST RIPENESS, THE WHEAT BEING GATHERED AND DRIED ON THE STRAW.

Groups.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.
Ash	4.81	4.16	3.24	2.52	2.16	2.07	1.82	1.80	1.68	1.79	1.77	1.59	1.87	1.67
Proteins ..	17.80	17.30	15.36	14.30	13.75	13.15	13.64	14.55	15.40	16.24	14.96	16.59	16.56	17.26
Amides ..	2.83	1.40	1.01	0.91	0.78	0.56	0.51	0.50	0.44	0.50	0.44	0.61	0.62	0.56
Fats	4.32	3.09	2.64	2.51	2.31	2.38	2.45	2.59	2.60	2.44	2.50	2.37	2.46	2.52
Crude Fibre ..	8.69	6.96	5.50	4.56	3.72	3.30	3.10	3.11	3.01	3.03	3.04	2.98	3.00	2.96
Pentosans ..	13.54	12.84	12.28	11.10	9.73	9.66	9.32	8.82	8.50	8.41	8.08	8.16	8.33	8.63
Dextrins ..	2.00	3.07	2.86	2.66	2.26	2.11	1.94	1.75	1.72	1.83	2.46	1.77	1.79	1.75
Sucrose ..	2.95	2.80	2.26	1.94	1.42	1.45	1.45	1.43	1.28	1.44	1.52	1.51	1.53	1.50
Glucose ..	1.55	0.64	0.17	0.08	0.07	0.05	0.05	Trace	0.01	Trace	Trace	Trace	Trace	Trace
Starch and Undetermined	41.51	47.74	54.68	59.42	63.80	65.27	65.72	65.45	65.36	64.32	65.23	64.42	63.84	63.15

(*Bull.* 53, 1898, *Arkansas Agric. Expt. Stn.*)

418. Effect of Shade on Wheat Composition, Thatcher and Watkins.—As a result of comparative experiments made on the same wheat grown and ripened in sunshine and in shade respectively, Thatcher and Watkins find that the shaded wheat gives grains which are darker in colour. The protein is slightly higher and the starch lower than in the unshaded samples (*Jour. Amer. Chem. Soc.,* 1907, 764).

419. Frosted Wheat, Shutt.—Shutt finds on analysis that the protein content of frosted wheat is considerably higher than that in the unfrosted mature grain. The effect of frost is a premature ripening, or rather drying-out of the grain, with as a consequence, a kernel high in protein, but low in starch (*Jour. Amer. Chem. Soc.,* 1905, 368).

CHAPTER XV.

THE STRENGTH OF FLOUR.

420. Physical Properties of Flour.—In addition to its purely chemical composition, flour possesses certain physical properties which are of the highest importance to the baker, and consequently to the miller. These are "Strength" and "Colour." Flavour may also be mentioned, but this is essentially rather a matter of the palate than of chemical analysis, hence a judgment of the flavour of flour is best made by the actual consumer. These three properties of Strength, Colour, and Flavour, together with certain side issues connected with them, largely, if not entirely, determine the commercial value of a sample of flour.

421. Nature of Strength.—There are certain desirable qualities in a bread-making flour which commonly go together. Among these are a large relative yield of bread due to a high water-absorbing capacity, the power of producing a large loaf, that of producing a bold loaf, and a well-piled loaf. In consequence of these usually, but not invariably, accompanying each other, strength has been variously described as the property of causing one or other of these effects. In the 1895 edition of this work the following definition is given:—**Strength, then, is defined as the measure of the capacity of the flour for producing a bold, large-volumed, well-risen, loaf.** It is in this sense that the word is throughout used in the present work.

422. Home-grown Wheat Committee's Definition.—Humphries and Biffen, in a paper on "The Improvement of English Wheat," define their view of "strength." They dismiss those estimates which are based on measurements of water-absorbing power to produce a dough of standard consistency, remarking that bakers do not make the various kinds of flour up to one and the same consistency in the doughs. To give the best possible loaves, some require to be made into "tight," others into slack doughs, and the baker simply learns by experience what particular degree of consistency is the most suitable for the flour in hand. Number of loaves per sack is another common method (being a variant of water-absorbing power). But some Russian and most Indian wheats give a large number of loaves but small and close of texture. This also is regarded as unsatisfactory. "A third view, apparently largely adopted by the bakers, is to judge strength by the way a flour behaves in the doughs, by its toughness, elasticity, freedom from stickiness, etc.; in other words, by the facility with which large masses of dough can be handled in the bakehouse. It seems more satisfactory to regard them as separate characteristics, for though of undoubted importance to the baker, they are not necessarily associated with the production of satisfactory loaves. The fact that some of the Russian wheats from St. Petersburg or Reval are esteemed strong, but work very badly in the doughs, will show the necessity for this distinction."

"The definition finally adopted by the Committee [Home-grown Wheat Committee of the National Association of British and Irish Millers] is, that **a strong wheat is one which yields flour capable of making large well-piled loaves,** the latter qualification thus excludes those wheats producing large loaves which do not rise satisfactorily. To estimate the strength of any particular sample of wheat then it is necessary to grind it and make the final tests in the bakehouse.''

The baking tests were carried out in the following manner:—''In the first place the baking trials are made with sufficient flour to yield a batch of about half-a-dozen loaves—the 'cottage' shape being considered the most satisfactory. With each set to be tried, loaves are baked from flour whose quality has been accurately ascertained. To these standard loaves a certain number of marks are assigned, and by comparison the baker records in marks his opinion of the strength of the flour under test. On this arbitrary scale the strongest wheats in commerce mark about 100, 'London Households' 80 to 85, and average English 60 to 65. The tests are always carried out by a man who devotes the whole of his time to this kind of work, and repeated trials have shown that they may be relied upon to express the strength with substantial accuracy'' (*Jour. Agric. Science,* 1907, II., 1).

This definition of strength is practically a paraphrase of that of one of the authors, previously quoted. In the one there is the expression ''well-risen,'' and in the other ''well-piled''; the latter term being employed to exclude large loaves which do not rise satisfactorily. A large loaf of coarse and ragged texture, and full of big holes, would not be regarded as either well-risen or well-piled.

423. Definition of Pile.—An explanation of the meaning attached to the word ''pile'' may here be of service. It is stated on the authority of a well-known Scottish baker, that the baker's use of the word originated in Scotland. Their very high close-packed loaves are smeared on the sides with melted lard before being placed in the oven. They are then easily pulled asunder, and the surface of the separated sides should have a smooth silky texture, a texture in fact recalling the ''pile'' of velvet. Such loaves are said to have a good pile, or to be well-piled. A good pile is associated with the same fine evenness of texture throughout the interior of the loaf, and hence the term has acquired the secondary meaning of an even, finely vesiculated, and silky texture of the substance of the loaf.

424. Value of Baking Tests.—Any carefully devised method of making baking tests can scarcely fail to differentiate strong from weak flours. The difficulty is with those of intermediate and approximating character and quality, and here much must depend on the suitability of the method of working to the particular flour. To give an example of what is meant, suppose a baker of one district adopts a four hours' system of fermentation, and another a six hours' system. A flour which is just exactly ripe at the end of four hours would appear much stronger to the four hours' baker than to the latter. Conversely a six hours' flour would be relatively strong to the six hours' baker and weaker to the four hours' workman. An alternative method would be to allow the fermentation to proceed to the best possible point for each particular flour and then bake it. This, however, introduces another element, in which there would almost certainly be considerable variations in judgment. As a result of variations such as these, it is probable that out of six baking experts no two would arrange a series of flours in quite the same order. Therefore, though Humphries' and Biffens' baking tests may be regarded as comparative among themselves, the reservation must always be borne in mind that there is no absolute and unvarying standard of strength. That flour is strongest which under the particular conditions of fermentation employed or required by any particular baker or district best conforms to the definition previously given of strength.

425. Conditions requisite for Strength.—A loaf of bread consists of a baked aerated mass of elastic dough. The first requisite of a strong flour is that there must be a sufficiency of sugar or other material available for fermentation and consequent production of gas in the dough. As dough fermentation involves a series of changes in which the distention by gas is but one, the source of gas must be sufficient for its continuous production, not only at the earlier stages, but throughout the whole process, and essentially during that period in which the loaf is acquiring its final shape and volume; that is to say, some little time before and after it is placed in the oven.

The next there must be some substance present in the flour which shall be capable of retaining a sufficiency of the gas generated in the dough, and elastic enough to be evenly distended by such gas. According to the kind of loaves to be made, the requirements for strength somewhat vary. If the bread is to be baked in a tin, it is supported on all its four sides, the top only being open; the same holds good, though to a slightly lesser degree, in close-packed oven-bottom bread, where the loaves support each other. For bread of this kind, the dough may be very soft and even "runny," provided it is elastic and of good gas-retaining capacity. But when the bread is baked into crusty loaves, whether of the cottage or Coburg type, the dough must not only be elastic and gas-retaining, but it must also possess sufficient rigidity to maintain its shape when standing alone and independently. Otherwise it may make a large but flat loaf, and not a bold well-risen one. The requisites necessary for strength under one of these sets of conditions are not precisely the same as in the other.

It is generally recognized that the constituent of wheaten flour in virtue of which its dough possesses these qualities of gas-retaining power and elasticity, is that known as gluten, that curious body largely composed of gliadin and glutenin. There must be sufficient gluten present to adequately retain gas and confer elasticity. Too much may be injurious, inasmuch as it may offer too great a resistance to the action of the distending gas; the consequence of this is the production of small and what are sometimes called "gluten-bound" loaves. Further the gluten must be of the right quality, it must be sufficiently impermeable to gas; it must be highly elastic, yielding readily to distention without breaking, and yet it must be sufficiently rigid, particularly in the case of crusty loaves, to maintain a well-upstanding bold shape. Quantity and character of gluten may to a certain extent compensate each other. If the gluten is exceptionally good, a little less of it may suffice, while slight deficiency in quality may be made up by a little extra in amount. Added to all this, important changes are going on in the gluten during the whole of the time of its fermentation. Normally, it is softening as fermentation proceeds, and becomes more yielding and gas-retaining during that operation. There comes a time, however, when the gas-retaining power is at its best, and further change simply injures and diminishes its tenacity. The art of the baker in part consists in so balancing all these various factors as to get the best possible result out of the flour with which he is working.

426. Commercial Wheat Testing, Snyder.—In 1905, Snyder communicated a paper on this subject to the American Chemical Society in which he first points out that the percentage of proteins in a flour is not necessarily a measure of its value for bread-making purposes. The following are some examples taken from the work of the Minnesota Agricultural Experiment Station:—

Grade of Flour.	Protein per cent.	Commercial Rank of Loaf.
First Patent	13.19	1
" "	14.47	2
Second "	14.15	5
" "	15.32	9

The following determinations are recommended as having given the best satisfaction in flour-testing: Moisture, ash, total nitrogen, gliadin nitrogen, granulation, absorptive capacity, and colour.

Moisture.—Especially helpful, as an excessive moisture content, above 13, has a tendency to induce fermentative changes.

Ash.—The determination is exceedingly useful in establishing the commercial grade of flour. First and second grades of patent flour invariably contain less than 0.48 per cent. of ash; in case a flour contains 0.5 per cent. of ash it would not be entitled to rank with the patent grades. Straight grade flour rarely contains more than 0.55 per cent. of ash, while the first and second clear grades contain higher amounts, 0.8 and 1.75 per cent. respectively.

Nitrogen content.—The best bread-making flours have a total nitrogen content of from 1.8 to 2.1 per cent. A lower figure than 1.5 per cent. indicates deficiency in gluten, and poorer bread. Flours containing an excess over 2.1 do not as a rule have improved bread-making values, as a very high gluten is not beneficial for bread-making purposes.

Gliadin Nitrogen.—The principal proteins of flour being gliadin and glutenin, it has been believed that their ratio determines largely the value of the glutinous material for bread-making purposes. Snyder finds, however, that "during some years as high as 70 per cent. of the total nitrogenous material of wheat is soluble in 70 per cent. alcohol, while in other years flour from wheat grown under similar conditions contains as low as 45 per cent. of its proteins soluble in 70 per cent. alcohol, and that these differences have been associated with only minor variations in the size of the loaf or general bread-making value of the flour."

Snyder believes that the percentage of gliadin in a flour is of more importance than the gliadin-glutenin ratio. In flours from the same wheat, the lower grades contain more total protein, but proportionately less gliadin than the higher ones. He also finds that any slight increase of acidity of the grain materially influences the gliadin percentage, which fact is shown in the following table:—

Constituents, etc.		FLOUR.		
		First Patent.	Second Patent.	Clear Grade.
Ash	per cent.	0.39	0.47	0.84
Protein	"	13.56	14.70	7.27
Gliadin, of total Protein	"	59.07	56.25	54.21
Acidity	"	0.07	0.08	0.12
Commercial rank of loaf	"	I	II	III

Snyder does not find gliadin to be of uniform composition, there being as great a difference as one or more per cent. in the nitrogen content of gliadin from different wheats milled under similar conditions. This suggests that gliadin is lacking in definite chemical composition, possibly as a result of wheat containing more than one protein soluble in 70 per cent. alcohol. He concludes that wheat gliadin is not as constant in chemical composition or physical properties as would be expected of a definite chemical compound.

Granulation.—This should be of medium fineness as such insures more complete digestion and absorption of the nutrients of flour by the body.

Colour.—This is one of the main factors in determining flour value, as each type of wheat has a tendency to produce flour of a distinct shade.

Bread-making Tests.—As yet chemical tests are not capable of accurately determining the bread-making value of a flour. They often indicate, however, why a flour is deficient in desirable bread-making characteristics, and from the chemical tests ways are suggested for improving the flour, but the actual bread-making value can be determined only by comparative bread-making tests. These give accurate data, including absorptive capacity and consequent yield. (*Jour. Amer. Chem. Soc.*, 1905, 1068).

With an excess of nitrogen the "gluten-bound" condition before referred to comes into operation. The abstract of this paper is purposely introduced here because of the strong expression of opinion as to effect of the ratio of gliadin to glutenin on the quality of a flour. Snyder's authoritative statement as to variations in the composition of gliadin also deserves careful attention. It should be compared with that following of Wood, paragraph 428. Snyder ultimately falls back on the baking test as most accurately determining the bread-making value of a flour.

427. Crude Gluten, Norton.—Norton has made a very full analysis of crude gluten as obtained from durum flour. The gluten was washed out, partly dried, finely ground and again dried until it ceased to lose weight at 100° C. On analysis it then gave the following results:—

Fats or ether extract	4.20	per cent.
Carbohydrates other than fibre	9.44	"
Fibre	2.02	"
Mineral Matter	2.48	"
Gliadin	39.09	"
Glutenin	35.07	"
Globulin, 10 per cent. NaCl extract	6.75	"
	99.05	

The gliadin was first removed from the gluten by alcohol, the residue was then extracted with 10 per cent. sodium chloride solution for globulin, and the residue finally extracted with 0.2 per cent. potassium hydroxide. Nitrogen was determined in each extract and multiplied by 5.7 for protein. From the above analysis, crude gluten may be regarded as consisting of about 75 per cent. of true gluten (gliadin and glutenin) together with other matters as indicated, and which include approximately 7 per cent. of non-gluten protein matter.

In summarising his results, Norton points out that the crude gluten of flours is very close in amount to that of total protein (N × 5.7), the variation being in a number of samples from an excess of crude gluten of 2.31, to a deficit of 1.30. As a rule the crude gluten is the higher for straight and low grade flours, nearly the same for patents, and less for whole wheat meal. It follows that crude gluten is a body in which there has been a loss of non-gluten proteins, more or less balanced by the retention of non-protein matters. Crude gluten is a very rough expression of the gluten content of a flour or wheat, and the determination has but little worth in the valuation of flours. The determination of total nitrogen and gliadin-nitrogen with expression of the ratio of gliadin to total protein (N × 5.7) seems to be the best simple method at hand for estimating the gluten content and ascertaining the character of the gluten in the valuation of wheats or flours (*Jour. Amer. Chem. Soc.*, 1906, 8).

Any review of opinions as to the value of gluten determinations is best postponed until a later stage. Meantime, the results of a very complete analysis of crude gluten is here placed on record. The most noticeable feature is the retention of 6.75 per cent. of globulin, a non-gluten protein. The comparative purity of crude gluten must depend somewhat on the thoroughness of the washing treatment; it will be observed that in the 1895 edition of this work about 80 per cent. of crude gluten is assumed to be true gluten. This was determined by a direct nitrogen estimation and substantially agrees with the sum of gliadin, glutenin, and globulin found by Norton.

Chamberlain, another American chemist, practically agrees with Norton and affirms that the determination of gluten is not able to yield any information that cannot be gained either from the determination of total proteins or that of the alcohol-soluble and insoluble proteins (*Jour. Amer. Chem. Soc.*, 1906, 1657).

428. The Chemistry of Strength of Wheat Flour, Wood.—This subject has been dealt with in papers published by Wood in the *Journal of Agricultural Science*, of which the following is a statement of his chief conclusions:—It may be regarded as proven that neither the absolute percentage of gliadin in the flour, nor the ratio of gliadin to total protein gives satisfactory indications of strength. Strength may be separated into at least two independent factors, those of volume and shape. In investigating the volume factor, Wood attaches great importance to the presence of sugar or sugar-producing substances in the dough. Summarising a number of experiments he states that they "seem to justify the conclusion that the capacity of a flour for giving off gas when incubated with yeast and water is the factor which in the first instance determines the size of the loaf." Particular attention should however be paid to the rate of gas evolution in the later stages of fermentation, as this is shown to be more directly connected with the size of the loaf. (*Wood, Journ. Agric. Science,* 1907, **2**, 139).

The suggestion in this paper that strength runs parallel with percentage of sugar is somewhat contrary to the hitherto generally accepted views. Thus the descriptions "a weak sweet flour," and "a strong, harsh, dry flour" are very familiar. A reference to the 1895 edition of the present work shows (page 291) that No. 2 Calcutta yields 8.34 per cent. of soluble extract, and (page 339) that the loaf is small and runny, devoid of texture, and foxy. On the other hand reference (page 292) shows that a sample of No. 1 American Hard Fyfe Wheat, yielded 4.35 per cent. of soluble extract, while the corresponding Spring American patent flour (page 338) yielded a loaf which was very bold and of good texture, but with a tendency to become somewhat rapidly harsh and dry, and comparatively flavourless. No determinations were made of sugars, but it is practically certain that they rise and fall with the total soluble extract. In paragraph 427 an account is given of some investigations of durum wheat by Norton. He there remarks that though all the durum flours have high gluten and sugar contents, yet the bread from many of the poorer durum wheat flours neither rises during the fermentation nor in the oven.

429. Effect of Sugar on Flour.—An interesting side-light is thrown on the effect of the presence of sugar in flour by the following experiments. In sweet biscuit doughs it is well-known that the physical condition of the dough is materially affected by the presence of the sugar. Thus a dough made from 100 grams of flour and 50 grams of water is much stiffer than one made from 100 grams of flour, 20 grams of sugar, and 50 grams of water, the latter being soft and sticky. For example, with such doughs, when tested with the viscometer, the following results were obtained. In order that the sugar dough should register equally the water had to be reduced to slightly less than 40 grams thus:—

		Viscometer Time.
I.	Flour 100, water 50	106 seconds.
II.	Flour 100, sugar 20, water 50	9 "
III.	Flour 100, sugar 20, water 48	16 "
IV.	Flour 100, sugar 20, water 46	28 "
V.	Flour 100, sugar 20, water 44	50 "
VI.	Flour 100, sugar 20, water 42	64 "
VII.	Flour 100, sugar 20, water 40	86 "
VIII.	Flour 100, sugar 20, water 38	364 "

for the half descent of the viscometer piston.

In view of these facts, tests were made on behalf of a firm of biscuit manufacturers, and communicated to them by one of the authors in 1902. Particulars of the flours are given. The sugar was supplied by the firm in question and gave the following results on analysis:—

Cane Sugar from opticity	98.45 per cent.
Reducing Sugar as Glucose	0.80 "
Water	0.10 "
Mineral matter	0.04 "

I. Doughs were made with flour A and B. The wet and dry gluten were determined by washing and drying; the true gluten by a Kjeldahl estimation on dry gluten; gliadin by dissolving the wet gluten with 70 per cent. alcohol, filtering and Kjeldahl estimation on the filtrate; glutenin by subtracting gliadin from the true gluten.

II. Doughs were made from 100 parts of flour and 20 parts of sugar (sugar-dough). The gluten was washed out with water, and weighed wet and dry. True gluten was determined as before. Gliadin was determined by dissolving wet gluten with 70 per cent. alcohol, containing to 100 parts of alcohol, 20 parts of sugar (sugar-spirit), filtering, and a Kjeldahl estimation on the filtrate; glutenin, by subtracting gliadin from true gluten.

	A.		B.	
Constituents.	Ordinary.	Sugar-dough.	Ordinary.	Sugar-dough.
Gluten, wet	37.2	35.9	26.7	23.9
" dry	11.3	11.7	8.2	7.7
" true	10.4	10.0	7.5	7.2
Gliadin ex Gluten ..	3.6	7.2	3.0	5.6
Glutenin	6.8	2.8	4.5	1.6

In all cases the sugar caused a diminution of the quantity of gluten recovered, except in the case of the dry gluten of flour A. When extracted with alcohol, much more of the gluten was dissolved by the sugar-spirit, than the ordinary alcohol, showing that sugar has a marked solvent action on wet gluten. (As all these gliadin determinations were made in the presence of excess of carefully washed precipitated chalk, $CaCO_3$, there could have been no free acid present.)

In the next place, the total protein of the flours was directly estimated by Kjeldahl's method. The proteins soluble in water were determined by directly treating the flour, filtering and Kjeldahl's process on the filtrate. The proteins extracted by a 20 per cent. aqueous sugar solution were similarly determined. The proteins soluble in 70 per cent. alcohol were estimated by direct treatment of the flours, and a Kjeldahl estimation on the filtrate. The proteins similarly dissolved by 20 per cent. of sugar in 70 per cent. alcohol (sugar-spirit) were also determined. The following are the results in percentages obtained on the same two flours:

Constituents.	A.		B.	
Total Proteins	11.6	11.6	9.9	9.9
Proteins soluble in Water ..	1.0		0.5	
" " Sugar-water		1.5		2.5
Gliadin and Glutenin	10.6	10.1	9.4	7.4
Soluble in Alcohol, Gliadin ..				
" " "Sugar-spirit" ..	6.4	7.5	4.6	5.7
Insoluble, Glutenin	4.2	2.6	4.8	1.7

It is assumed here that water and sugar-water respectively do not dissolve the same proteins as are dissolved by alcohol and sugar-spirit; probably however there is some overlapping. As the experiments are comparative this does not affect the point under consideration. It will be noticed that in every case there is an increased solvent power exerted when sugar is present. These tests were confirmed by others on four other samples of flour. In all cases, sugar-spirit dissolved considerably more protein than did plain alcohol. Sugar diminishes rather than increases the water absorptive power of the flour. In small quantities it is very possible that its solvent action on the gluten may effect sufficient softening to increase the gas-retaining power of the dough and thus indirectly increase the strength of the flour.

430. The Shape of the Loaf, Wood.—Following up his previous paper, Wood made a subsequent communication on what he regards as the second factor of strength, viz. that which decides the shape of the loaf, and this was tentatively ascribed to the soluble salts present in the flour. A further investigation was made of this hypothesis, with the result that Wood concluded that the variations in coherence, elasticity, and water content, observed in gluten extracted from different flours, are due rather to varying concentrations of acid and soluble salts in the natural surroundings of the gluten than to any intrinsic difference in the composition of the glutens themselves. These properties must undoubtedly have a direct bearing on the power which some flours possess of making shapely loaves. I suggest therefore that the factor of strength on which the shape of the loaf depends is the relation between the concentrations of acid and soluble salts in the flour." The author of the paper realises that his "results are at present only in what may be called a suggestive state." (*Wood, Jour. Agric. Science,* 1907, **2,** 267.)

431. An Analysis of the Factors contributing to Strength in Wheaten Flour, Hardy.—Hardy elaborated and explained his views on the relation of strength to electric potential in a paper read by him at the meeting of the British Association for the Advancement of Science, 1909. He compares dough to rubber loaded with solid particles, the gluten being the analogue of the rubber, and the starch contributing the solid particles. He goes on to say:—There has, so far as I know, been no exact work upon the influence of the size and number of the starch grains upon the mechanical properties of dough; in the absence of such information it is idle to pursue the point further. This may, however, be said: judging by what is known of the influence of embedded small particles in other cases, the power of the dough to retain its shape may be due in some cases primarily to the nature and number of the starch grains. But the essential active agent is the protein-complex gluten.

Now gluten, even though it be prepared from the best Fife flour, *has of itself neither ductility nor tenacity.* In presence of ordinary distilled water it partly dissolves, the residue—the larger portion—forming a semi-fluid sediment destitute of tenacity. Why? Because tenacity and ductility are properties impressed on gluten by something else—namely, by salts, by electrolytes, that is, which may be organic and may therefore be unrepresented in an ash analysis.

This being the case, it is obvious that any attempt to correlate strength with the physical properties of gluten washed out in the ordinary way must end in failure, since the properties of washed gluten depend upon the electrolytes which happen to be left in after the washing is concluded.

Electrolytes—that is to say salts, acids and alkalies—intervene in two absolutely distinct ways. They control the physical properties of the gluten in the dough, and they must also profoundly modify the temperature relations and the rapidity of the change undergone by the gluten and other constituents of the dough in the process of baking—a change which, so far as the proteins are concerned is, broadly speaking, a lowering of solubility. We know something of the way in which they act on gluten in the dough, but of the more complicated action during temperature changes we know nothing; it is possible that the same electrolyte may increase the mechanical stability of the loaf in the dough and yet diminish it in the oven.

The writer next summarises the results of Wood's experiments before described, in which it is shown that certain very dilute acids disperse gluten in fine particles, which are so changed that they actually repel one another, such repulsion being overcome and cohesion restored by the neutralisation of the acid or the addition of any salt such as common table salt. The cohesion of gluten is due to the salts naturally present; and their removal, as by washing with distilled water, causes the breaking down of the gluten. When gluten is thoroughly extracted with distilled water it loses cohesion and disperses as a cloud, not owing to the action of the water, but because of the faint acidity due to the carbonic acid dissolved from the air. In the absence of salts, this is sufficiently strong to destroy cohesion. In cases where the quantity of salt is insufficient to counteract that of the acid, the gluten is in a state of colloidal solution, containing exceedingly fine particles of gluten. With an increase of salt the particles become continually coarser, until finally they run together into a coherent mass of gluten. As the salts present still further increase, there is still further separation of water, and as the water-holding power of the protein diminishes, so also does its ductility, while at the same time there is an increase in the tenacity.

Electrolytes, therefore, do more than confer on gluten its mechanical properties; they determine also its power of holding water. They also determine the water-holding power of any other colloid matter present in the dough.

Acids and alkalies destroy cohesion and disperse the particles of gluten just as they produce and stabilise non-settling suspensions in many types of colloidal solution—namely, by the development of a difference of electric potential between the particles and the water. The curve which connects the potential difference with the concentration of acid has the same form as that which represents the region of gluten non-cohesion.

The foregoing analysis of the factors which control the physical properties of gluten in moist dough lead us to a brief analysis of the source of "strength" in flour. It must be borne in mind that loaf-making includes two distinct operations, the making and incubation of the dough and the fixation of the incubated dough by heat. Every factor which contributes to the rising of the dough—that is, to the size of the loaf—and to the power of the dough to preserve its shape (saving only the vital activities of the yeast plants) intervenes also in the fixation of the dough, where it may undo what it has already done. Successful incubation depends upon: (1) The suitability of the dough for the active growth and production of carbonic acid by the yeast plant, which again depends upon the concentration of sugar, the intrinsic diastatic power of the dough and the concentration and nature of the electrolytes. (2) The physical character of the dough, which depends upon the size, shape, and number of starch grains, the nature and concentration of the electrolytes, since these determine the physical properties of colloids present, notably the gluten. The electrolytes will also direct those molecular rearrangements which occur during the baking process and which give fixity and stability to the entire structure. (*Supplement,* June 4 ,1910, p. 52, *Jour. Board of Agric.*)

Snyder had previously dealt with the effect of variations in the quantity of starch on the character of dough, and concluded that they were without any marked effect. One of the authors had previously shown that with flours having different quality glutens, such glutens maintained their individual character through a long range of variations produced by the addition of starch. Hardy advances the paradox that gluten, even of the strongest flour, "has of itself neither ductility nor tenacity." The correctness of this dictum depends on the definition of the word "gluten." In the primary sense in which that word is almost universally employed, gluten is the name of that elastic, ductile, and tenacious mass, *whatever may be its composition,* which is obtained by washing dough in the recognised manner. Gluten has hitherto been supposed to consist essentially of protein matter, but Wood's researches go to show that certain salts exercise a profound influence on its character. The presence of these may in fact be regarded as a necessity, and if they be removed the remaining body or bodies is no longer gluten in the generally accepted sense of the word. Putting it another way, the proteins of gluten, *in the absence of electrolytes,* are collectively neither ductile nor tenacious. But from this it does not follow that no relation exists between the strength of a flour and the physical properties of its washed-out gluten. It is generally agreed that the physical strength of dough, *i. e.,* its ductility and tenacity, depends on the quantity and quality of the gluten it contains, using that word in its evident sense as including proteins, electrolytes, and all that goes to give that body its essential characters. As a matter of fact, the general rule is that a properly washed-out gluten correctly reflects by its quantity or quality, or both, the strength of the flour from which it was obtained. To this the exceptions are remarkably few, and interesting evidence of the value of this test was given by Saunders in the course of a paper read by him at the same meeting, and quoted at the close of this chapter. When gluten washing is done with suitable water, sufficient electrolytes remain in the gluten to conserve its characteristic properties, and enable a judgment to be based thereon.

The writer's speculations as to the effect of electrolytes through the whole process of baking, as well as of fermentation, are of interest, and may very probably indicate the direction in which the future solution of many problems may be found. The relationship of cohesion of gluten to electric potential is clearly indicated, but the question remains whether any part of the operations of baking falls within, or even approaches, the region of non-cohesion of gluten. Taking the figures given in the writer's paper, about 22 grains of common salt per 1,000 litres is sufficient to neutralise the maximum disintegrating effect of sulphuric acid. The word *grain* may possibly be a misprint for *gram,* and if so the figure is 22 grams per 1,000 litres. Assuming this latter to be correct, then the degree of concentration is 22 grams per 1,000 litres = 22 grams per 1,000,000 grams of water. In bread-making salt is always used, and to an extent of about 3 lbs. to the sack of 280 lbs. of flour. To the water, salt is taken in the approximate proportion of 2 lbs. of salt per 100 lbs. of water, which equals 2,000 grams of salt to 1,000,000 grams of water, or about ninety times the concentration for the critical point in Hardy's curve. The question of the influence of sugar upon strength has been already discussed, and with it much of the importance or otherwise of the diastase of dough is closely connected. Snyder's work already referred to goes to minimise the effect of starch grains.

432. Size of Starch Grains, Armstrong.—The size of wheat starch grains was also referred to by Armstrong in a paper read at the same meeting. He states that microscopic examination shows flour to consist of starch granules of three different sizes. The smallest granules which preponderate in amount are from 3 to 5 μ in diameter, the largest granules are about 30 to 35 μ, and there are also granules of intermediate size. The microscopic examination of a large number of flours of different origin has shown that the large granules very in number from 6 to 1½ per cent. of the total number of granules. In other words, in one flour as much as 30 to 40 per cent. of the total weight of starch is in the form of large grains, whilst in another only 7 to 10 per cent. is in this condition.

Before a starch grain can be converted into sugar the cellular envelope has first to be destroyed. Obviously, when the envelope of the large granule is destroyed a much larger proportion of starch is rendered available than when the contents of a small granule are liberated.

Whymper has made a microscopic study of the changes occurring during the germination of wheat. He finds that the larger and more mature granules are the most readily attacked by the enzymes of the plantalet. Though there is no general relation between the size of starch granules of different origin and the ease with which they are attacked by diastase and other agents, it appears that the larger granules of any particular starch are affected sooner than the smaller granules. (*Supplement,* June 4, 1910, p. 49, *Jour. Board of Agric.*)

Armstrong's examination of starch is evidently the result of his conclusions that flour does not contain sufficient sugar for bread-fermentation, and that the requisite sugar is always provided by the hydrolysis of starch.

With the object of further investigating the effect of different sizes of starch granules, the authors made the following experiments. A strong American flour was taken, being No. 6 in the Table of Flours and Wheats, described in Chapter XXIII. To 80 parts of this flour there were added and thoroughly mixed 20 parts of potato, wheat, and maize starches respectively. The potato starch granules are considerably larger than those of wheat, while those of maize starch are very much smaller. [Compare with dimensions given in Plate I and accompanying description in letterpress.] In these three mixed flours the average size of the starch granules was therefore increased in the first, unaltered in the second, and diminished in the third. The original flour yielded 15.02 per cent. of dry gluten, which gives the mixed flours an amount of 12.01

per cent. in each case. Viscometer determinations of water absorption gave the following results in quarts per sack:—

Flour only.		Flour & Potato Starch.		Flour & Wheat Starch.		Flour & Maize Starch.	
Quarts.	Seconds.	Quarts.	Seconds.	Quarts.	Seconds.	Quarts.	Seconds.
65	315	65	90	—	—	—	—
—	—	—	—	66	81	66	102
—	—	**66.5**	**60**	—	—	—	—
—	—	—	—	**67.0**	**60**	—	—
68	227	68	42	68	48	**68**	**54**
70	**52**	70	27	70	28	70	37
72	43	—	—	—	—	—	—

The figures in heavier type are those which practically agree with the sixty seconds standard. The whole of the starched flours have fallen off in water-absorbing power. Throughout the series of tests, this falling off has been greatest with the potato starch and least with that of maize. The difference may probably be accounted for by the greater surface offered by the smaller starches in proportion to their weight.

Baking tests were next made with the flours with the special object of observing their strength behaviour both in the dough and the loaf. A stiff dough was made from each for crusty Coburg loaves. The water taken was in the same proportions as in the viscometer tests. Those from the three mixed flours fermented much more rapidly than did the unmixed flour, which latter made a bold sweet loaf, while the former on falling in the dough was unable to rise again either during fermentation or in the oven. The starch-mixed loaves were all distinctly over-worked and sour to the nose. A second test was made in which the three mixed flours were fermented for a shorter time, as nearly as possible three-quarters of that required by the unmixed flour only. In this case much better results were obtained, but all the doughs fell off in the latter stages of fermentation, and had comparatively little "spring" in the oven. The differences in behaviour were very slight; but if anything the potato starch loaf was least tough and "springy" (elastic) in the dough, and rose least in the oven. The wheat starch loaf came next, and the maize starch gave the best results of the three.

433. Water-soluble Phosphates in Wheat, Wood.—Professor Wood kindly forwarded to the authors in 1910 an advance note of experiments recently performed by him, of which the following is a summary:—Wood made a number of analyses of the water extract of different flours. The method used was to shake up 200 grams of flour with 2,000 c.c. of water containing a few drops of toluene to delay fermentation. The shaking was continued for one hour, and the mixture then filtered. Aliquot portions of the clear solution were then evaporated to dryness, and their content of phosphoric acid, lime, magnesia, chloride, and sulphate determined. He finds that in all the flours made from Fife wheat, the water soluble phosphate is high—over 0.1 per cent. of the flour, and the chlorides and sulphates very low. They also contain more magnesia than lime. Wood has examined about half a dozen samples of Fife, some grown in Canada and some grown in various parts of England, and they all agree in these respects. Weak wheats of the Square Head's Master type, and in fact all the wheats he has examined, except the Fifes, and one which came from Japan, contain from 0.8 per cent. to as low as 0.04 per cent. of water-soluble phosphoric acid, and correspondingly higher amounts of sulphate and chloride, and as a general rule more lime than magnesia. Wood has little doubt that the peculiar properties of the gluten of the Fife wheats is due to their high content of water-soluble phosphate, and believes that the determination of the water-soluble phosphate gives a great deal of information as to the character of the gluten content in a flour. (*Personal Communication,* May, 1910.)

434. Strength of Wheat Flours, Baker and Hulton.—This paper is marked by the writers' recognition of the fact that the strength of flour depends on more than one factor. In connexion with the enzymic activities of flour, they examined the effect of the proteolytic enzymes both of the flour itself and of yeast on gluten. It is of special interest to note the recognition they give to the possibilities of "profound change" in physical character of substances such as gluten without any corresponding chemical changes in the ordinary use of that term. They also consider that the gas concerned in the rise of bread, especially in the latter stages of doughing and the early part of baking, is derived from the starch of the flour. Gas retention is recognised by the writers as more important than gas production. Careful attention was given to the amylolytic enzymes of flour, and especially to the presence or absence of a liquefying enzyme. This they regard as having an important bearing on strength, and produce results in support of their conclusion. The difference in activity of flour diastase to soluble starch and starch *paste* respectively was made the subject of experiments by one of the authors, and recorded in the 1895 edition of this work. In summarising their conclusions, the writers emphasize the fact of its close connexion with gluten.

435. Present-day Conclusions.—In paragraph 425, in the early part of this chapter, it is laid down that there must be a sufficiency of sugar or other material available for fermentation in the dough. It has also been suggested that the presence of much maltose is evidence of unsoundness, and reference has already been made to the fact that certain very strong flours contain comparatively little sugar, while in others which are weak sugar is present in comparatively large quantity. Flours from sprouted wheats are comparatively weak and with high maltose contents; in such cases there is probably practical agreement with the view that the high sugar is associated with low strength. If wheat is gathered and milled in an unripe condition, there is again a lack of strength, and yet there is a relatively high percentage of sugar. Thus in the account given in paragraph 417 of Teller's researches on the composition of wheat at different stages of ripeness, it is shown unripe wheat contains more sucrose, 2.95 to 1.43 per cent., than ripe wheat at 1.44 per cent. (There is one rather anomalous figure, viz. 1.28 per cent. for the third day immediately preceding ripeness.)

Parenti states that the reducing sugar of flours is reduced during fermentation from 2.31 to 0.13 per cent.; that is a consumption of 2.18 per cent. In Wood's paper he lays great stress on the importance of sugar as a factor of strength, and remarks of one flour, that it cannot make large loaves because of the low percentage of sugar present. He accordingly tested the flours by a fermentation test, and 20 grams of flour and 20 grams of water (112 quarts to the sack) and 0.5 gram of yeast (7 lbs. to the sack) were taken and fermented at 35° C. (95° F.) for twenty-four hours, at the end of which time the volume of gas was observed. In the case of the lowest flours there was a gas equivalent of 1.6 per cent. of sugar, while the highest amounted to 2.6 per cent. of sugar. The flour with 1.6 is that before referred to as being deficient in sugar. Armstrong states yet more definitely that the amount of sugar actually present in flour is not sufficient to give the necessary volume of gas required in bread-making. Again, Ford and Guthrie, in *Jour. Soc. Chem. Ind.,* 1908. 389, state that they are of opinion that the greater part of the carbon dioxide liberated in panary fermentation must be derived from the starch of the flour. They quote an experiment in which on fermenting a flour in the usual way with yeast they obtained 350 c.c. of gas from 20 grams of flour, which corresponds roughly with the fermentation of 1.3 grams of sugar or 6.5 per cent. of the flour. Direct estimations gave respectively 0.82 per cent. of sucrose and 0.1 per cent. of reducing sugar in the flour, special precautions being taken to eliminate all diastase from the flour before the determination. Baker and Hulton also express the opinion that the carbon dioxide concerned in the rise of bread during the later doughing and the early period of baking has as its source the starch of the flour.

436. Fermentation Experiments by Authors.—In view of these opinions it was thought advisable by the authors to make some fermentation experiments which should be as nearly as possible conducted under precisely the same conditions as occur in actual practice. A baker was asked for samples of respectively the strongest and weakest flours he then had in stock, and supplied the following:—

A. A strong Spring American Patent Flour.
B. A very weak French Flour.

Doughs were made from each of these in the following manner:—

	A	B
Flour,	200 grams at 17° C.	200 grams at 17.5° C.
Salt,	2 grams.	2 grams.
Yeast,	1 gram.	1 gram.
Water,	100 grams at 31° C.	100 grams at 31° C.
Dough,	303 grams at 26° C.	303 grams at 26.5° C.

The following are the proportions of each ingredient per sack—salt, 2 lbs. 13 oz.; yeast, 1 lb. 6 2/5 oz.; and water, 56 quarts.

After being made, the doughs were transferred to enamelled steel beakers and weighed; after fermentation they were again weighed with the following results:—

	A	B
Weight of unfermented dough	301.6	298.7
„ „ fermented dough	299.8	296.6
Loss in weight during fermentation	1.8	2.1

Immediately after being weighed, each beaker was placed in a containing vessel of convenient size, and the lid fastened down so as to make an air-tight joint. This vessel was in turn submerged in a water-bath maintained at a constant temperature of 25° C. (77° F.) and fermentation was allowed to proceed for six hours. To the containing vessel was attached a leading tube through which the generated gas was passed, and was collected over brine and measured in the usual way. (The whole apparatus is described in paragraph 522, Figure 33.) The times and temperatures were practically copied from those in actual use, and covered the whole period to the arrestment of fermentation in the oven, they were in fact the same as those which the baker employed when working with flours of this stronger type. The volume of gas was read at the expiration of one and a half hours and every half hour until the six hours had elapsed. The results are recorded in the following table. The gas was collected at a temperature of 18.0° C. and 760 m.m. of pressure.

Time.	A. Strong Flour. Gas Evolved.		B. Weak Flour. Gas Evolved.	
	Total.	Per Half-hour.	Total.	Per Half-hour.
Start..........	0.0		0.0	
1½ hours........ .	40.0		35.0	
		23		36
2 "	63.0		71.0	
		47		54
2½ "	110.0		125.0	
		47		70
3 "	157.0		195.0	
		59		82
3½ "	216.0		277.0	
		80		100
4 "	296.0		377.0	
		87		105
4½ "	383.0		482.0	
		117		125
5 "	500.0		607.0	
		92		140
5½ "	592.0		747.0	
		113		136
6 "	705.0		883.0	

From the volume of gas evolved, its weight, and that of the sugar required for its production, are easily calculated. The results of such calculations are given in the upper table on the following page. In each pair of columns the first contains the various data as calculated on the dough as used; in the second column they are reckoned as percentages of the dried or water-free solids of the dough. In view of the very small loss of weight by the dough during fermentation, it must be assumed that very nearly all the alcohol remains in the dough and is weighed therewith.

A number of analytical determinations were also made on the flours and doughs at the close of fermentation respectively, the results of which appear in the lower table on page 282. For soluble matters 10 per cent. solutions of the flours were prepared, allowed to stand for half-an-hour in the cold, and filtered bright. No attempt was made to discriminate between previously existing sugars and those produced from the starch during this period of standing, as sugars from the both sources are in practice equally available for gas production from the start of the fermentation. With the fermented doughs, these were kneaded until as much as possible of the gas had been forced out; 50 grams were then taken, and washed for gluten in successive small quantities of tap water (from deep wells in the chalk). The washings were added together and made up to 500 c.c., including the starch, for the presence of which no correction was made. This solution was filtered bright and soluble matters estimated in the filtrate. It is interesting to place on record that on washing the dough with distilled water, at the end of the second washing the gluten, which at first separated out very well, became completely disintegrated. There was no tendency in this direction when tap water was employed.

Particulars.	DOUGHS.			
	A. Strong Flour.		B. Weak Flour.	
	As Used.	Dried Solids.	As Used.	Dried Solids.
Total volume of gas evolved in c.c.	705	—	883	—
Weight of gas evolved (CO_2), in grams	1.30	—	1.63	—
Approximate weight of sugar required for the production of the gas, in grams	2.82	—	3.53	—
Approximate weight of alcohol produced in grams	1.41	—	1.76	—
Weight of sugar required per 100 grams of dough, *i.e.* per cent.	0.93	1.58	1.18	2.05
Weight of alcohol produced per 100 grams of dough, *i.e.* per cent	0.46	0.79	0.59	1.02
Loss of weight during fermentation, per cent.	0.59	1.00	0.70	1.22
Sum of the two preceding quantities, which practically agrees with sugar required	1.05	1.79	1.29	2.24

A. STRONG FLOUR.

Constituents.	Flour.		Fermented Dough.	
	As Used.	Dried Solids.	As Used.	Dried Solids.
Moisture	11.29	—	41.11	—
Total Solids	88.71	100.00	58.89	100.00
Gluten, Wet	40.5	45.64	29.90	50.77
„ Dry	13.5	15.21	9.54	16.20
„ Ratio of Wet to Dry	3.0	3.0	3.1	3.1
„ True	10.23	11.53	7.32	12.43
„ „ Percentage of Dry	75.57	75.57	76.67	76.67
Soluble extract	6.12	6.90	4.12	6.99
Reducing Sugars as Maltose	1.48	1.67	1.00	1.70
Non-reducing Sugars as Sucrose	0.93	1.05	Nil	Nil
Added Salt	—	—	0.66	1.12

B. WEAK FLOUR.

Constituents.	Flour.		Fermented Dough.	
	As Used.	Dried Solids.	As Used.	Dried Solids.
Moisture	13.50	—	42.58	—
Total Solids	86.50	100.00	57.42	100.00
Gluten, Wet	30.5	35.26	22.22	38.68
„ Dry	11.1	12.83	7.10	12.36
„ Ratio of Wet to Dry	2.7	2.7	3.1	3.1
„ True	8.74	10.10	5.89	10.25
„ „ Percentage of Dry	78.74	78.74	83.04	83.04
Soluble Extract	5.76	6.66	5.44	9.47
Reducing Sugars as Maltose	1.17	1.35	1.30	2.26
Non-reducing Sugars as Sucrose	0.21	0.24	0.10	0.17
Added Salt	—	—	0.66	1.15

Baking tests were also made on the flours with the following results:—In each case 24 oz. of flour were taken. With A, 13½ oz. of water were required to make the dough, and with B, 12 oz. of water. With these quantities the consistency of the two doughs was the same. They were worked with the same quantities of yeast and salt, and at the same temperature. The dough from A was springy, tough, and wiry; that from B was dead and putty-like. The A dough was ready for the oven in five hours, and B in four hours. They were baked into crusty loaves, and awarded bakers' marks for strength, on the scale of maximum 100, minimum 50. The awards were A, 95, B, 60 marks. If there was any error it was in the direction of undue generosity to B. The difference in water-absorbing capacity is equivalent to 17.5 lbs. or 7 quarts to the sack of 280 lbs., and this figure agrees with the vendor baker's estimate of the water-absorbing power of the two flours in practice.

437. Consideration of Results.—In examining the results, the first subject is naturally that of the gas evolved. The quantity obtained from the strong flour must be regarded as amply sufficient to ensure the production of a bold well-risen loaf. The evolution increased until the end of the fifth hour, when for one reading there was a diminution. The slight irregularities were apparently due to the sudden liberation of gas by the "dropping" of the dough. The sugars obtained by direct extraction of the flour by cold water, 2.72 per cent. were considerably in excess of the amount required in order to produce the evolved gas, viz. 1.58 per cent. In each case, and throughout these comparisons, the percentages on the dried solids are taken. Turning next to the weak flour, there is considerably more gas evolved over the whole process of fermentation, and even to the end the evolution is more rapid than with the strong flour. The gas was evolved much more regularly, because, no doubt, of the less retaining power (greater porosity) of the weak dough. The total sugars of this flour amounted to 1.59 per cent. and are less than those required for the fermentation, viz. 2.05 per cent., by 0.46 per cent. Against this it must be remembered that with such a very weak flour a much shorter period of fermentation would be essential to the production of a moderately passable loaf, than would be employed with the stronger flour. A baker would probably give it no more than from two-thirds to four-fifths of the amount of fermentation that would be employed for the strong flour. If the dough were got into the oven at the end of the fifth hour, 607 c.c. of gas would have been evolved, as against 588 c.c., which amount is two-thirds of the 883 c.c. produced in six hours. This latter amount of gas requires for its production 1.37 per cent. of sugar as expressed in the dried solids of the dough, leaving a margin of 0.22 per cent. surplus of sugars in the flour. Taking these as extreme types of strong and weak flours, **the pre-existent sugars of flour, together with those readily-formed in the cold on the addition of water, are in themselves sufficient for the production of all gases necessary in the normal fermentation of dough.**

Comparing the above conclusion with those previously cited, Parenti notes a consumption of 2.18 per cent. of the flour, amounting to about 2.45 per cent. of the dried solids, while in the case of the authors' very strong flour, 1.58 per cent. only of sugars were required. Judging by recognised English methods, Parenti's doughs were considerably over-fermented. In Wood's fermentation tests, volumes of gas ranging from 131 to 345 c.c. were obtained from 20 grams of flour. Multiplying these numbers by 10 in order to compare the results with those obtained by the authors from 200 grams of flour, there is a minimum of 1,310 c.c. as against a working requirement of 705 c.c. with a strong and about 600 c.c. with a weak flour. Similarly, when Ford and Guthrie produced 350 c.c. from 20 grams of flour (or 3,500 c.c. from 200 grams), they obtained about five times as much gas as is evolved in the normal fermentation of dough.

If in flours of ordinary type, whether weak or strong, there are always sufficient pre-existent and readily-formed sugars for the usual requirements of fermentation, it is not very apparent that any excess of amylolytic enzymes over those necessary for the production of such readily formed sugars, has any direct bearing on the strength of the flour.

(And the enzymic activity of all flours seems sufficient for this particular purpose.) But so far as these recent experiments go, the following calculations are of interest:—

	A. Strong Flour.	B. Weak Flour.
Soluble Extract in Fermented Dough	6.99	9.47
Subtract added Salt	0.66	0.66
	6.33	8.81
Add Sugar consumed in Fermentation	1.58	2.05
	7.91	10.86
Subtract Soluble Extract of the Flour	6.90	6.66
Soluble Matters produced during Fermentation	1.01	4.20

In these particular instances there is, during ordinary fermentation, over four times as much diastatic action with the weak than there is with the strong flour. This result seems to be borne out by general experience, for strong flours are liable to produce dry flavourless bread, while that from the weaker varieties is more usually moist and sweet.

Humphries informs the authors that with the flours of some very hard, ricy wheats, there are insufficient pre-existent and readily-formed sugars to yield the quantity of gas produced in even the limited fermentation here described. It is suggested that such flours are, however, scarcely commercial varieties in their separate state.

438. Gas-retaining Power.—Comparatively recently the opinion has been expressed that the strength of flour depends not upon its gas-producing but on its gas-retaining power. This is only another way of formulating the old view that strength depends on the gluten of the flour.

439. Relation between Gluten and Proteins of Flour.—The foregoing researches serve to throw considerable light on the actual composition of gluten and its relation to the total proteins of the flour. Norton made a very complete analysis of crude gluten, which he found to contain about 74 per cent. of gliadin and glutenin, and about 7 per cent. of a non-gluten protein. The remaining 19 per cent. was made up of fat, carbohydrates, fibre, and mineral matter. These figures confirm the opinion in the 1895 edition that crude gluten contains about 80 per cent. of proteins as determined by nitrogen estimation. Norton points out that the percentage of crude gluten from flour roughly approximates to that of total protein present, there being a loss of non-gluten proteins, more or less balanced by the retention of non-protein matters; in his view evidently the proportions of the two are regarded as being fairly constant. In consequence he regards crude gluten as but a very rough expression of the protein content, and the determination as of but little worth in the valuation of flours. Chamberlain goes over much the same ground, and substantially agrees with Norton. He finds about 75 per cent. of proteins, and 25 per cent. of non-proteins in crude gluten. Of all the proteins present in *wheat* 60 to 65 per cent. are found in the gluten, and 35 to 40 per cent. are lost in the washings. Evidently all the bran proteins must of necessity be thus lost. He agrees that the balance of losses of proteins and retention of non-proteins make the gluten estimations agree roughly with the total proteins calculated from total nitrogen. A further and more important conclusion is that gluten contains less total protein than the sum of the gliadin and glutenin present in the wheat by about 15 per cent.; and consequently that the loss of proteins in the determination of gluten is at the expense of gliadin or glutenin, the true gluten proteins of wheat. He therefore regards gluten determinations as not being able to yield any information that cannot be obtained from determinations of total proteins and alcohol-soluble and insoluble proteins. If Norton's and Chamberlain's results both be regarded as accurate, Chamberlain's 15 per cent. loss would have to be increased by the 7 per cent. of globulin contained in the gluten, which is included in the total proteins, but is neither gliadin nor glutenin. Dealing, however, with the 15 per cent. loss only, in the case of a flour yielding 39 per cent. of wet gluten, and 13 per cent. of crude dry gluten, such weights ought to have been, had there been no loss, 44.85 per cent. of wet, and 14.95 per cent. of dry gluten. The question suggests itself, to what is such loss due? Is it caused by an actual failure to recover some 6 per cent. of wet gluten that was present in the dough and necessarily lost in the washing; or at the time of washing was this gluten, or its components gliadin and glutenin, in a non-elastic and non-adhesive condition, and therefore not gluten at all in the sense of possessing the physical properties of wet gluten? To the authors, the latter alternative seems the more probable, and consequently there may be present in dough, gliadin and glutenin constituents which at the time of making the estimation are not fulfilling the physical functions of gluten proper in the usually accepted sense of the term. Some light is thrown on this point by the gluten determinations made on the flours used for the fermentation experiments just described. That of the strong flour, A, was when washed at the end of an hour's standing, and dried, 15.21 per cent. of the dried solids. The corresponding fermented dough yielded 16.20 per cent. In the case of the weak flour, however, there was a slight diminution in the dry gluten of the fermented dough. Nitrogen determinations were accordingly made on the whole four dry glutens, and the results calculated into "true gluten." These figures are included in the foregoing table on page 282. The true gluten obtained from the fermented dough of the strong flour is 12.43 as against 11.53 per cent. on the flour. There is also an increase with the weak flour, the figures being 10.25 on the dough as against 10.10 per cent. on the flour. During fermentation therefore the quantity of proteins which possess the physical character of gluten show an increase. Recent research must therefore be regarded as confirming the view that crude gluten contains from 20 to 25 per cent. of non-proteins. Further, it goes to show that about 7 per cent. of the proteins present may be non-gluten protein, and that of the gluten proteins (gliadin and glutenin) some 15 per cent. of the total in the wheat or flour are not obtained in the gluten. Obviously, **a dry gluten determination must not be regarded as an estimation of the proteins of the wheat or flour.**

The above limitation being accepted, the question naturally arises as to what a gluten determination really is. The best answer seems to be that **a gluten determination is an estimation of the amount of those bodies which are in such a physical condition as to impart elasticity and gas-retaining power to the dough at the time when the determination is made.** The exact nature of its constituents is of secondary importance, and whether gluten consists of protein matter only, or of 75 to 80 per cent. of proteins together with a complement of non-proteins, does not affect the value for the purposes of comparison of the results obtained. A point worthy of consideration about gluten estimations is whether they might not be advantageously made on the dough at a stage of its fermentation when its strength is of the greatest importance. That stage by general consent would be when the dough is ready to go into the oven. This end might be attained by making the flour to be used for this estimation into a dough with yeast, salt, and water, in the proportions and at the temperatures employed in actual bread-making. The doughs would then be kept in a fermenting vessel at a constant temperature, such as that employed in the recently described experiments, for a time similar to that taken in the bakehouse for the completion of the fermentation of the dough. In order to prevent drying, the atmosphere of such a vessel should be kept saturated with moisture. If the gas evolution were simultaneously observed a still more complete record of the behaviour and properties of the flour would be obtained.

440. Mechanical Disintegration of Gluten.—It is a fact well-known in the experience of bakers that mechanical over-kneading kills, or "fells," a dough. The consequence is that a dough, which would ordinarily produce a bold well-risen loaf, becomes soft and putty-like, and yields small sodden bread, just as though a very weak flour had been used in its preparation. In practice, any serious injury from this cause is avoided by careful watching; further, the dough has while standing the power of recovery in some degree of its strength. It is not so well-known that such over-kneading materially alters the physical character of the gluten. In order to investigate the point, the following experiments were made with a very strong American wheat flour.

No. 1. The flour was made into a dough by hand-kneading, and the various determinations carried out on the gluten from this dough.

The total soluble matter and proteins soluble in water were determined direct on the flour.

The water absorption by viscometer was determined on hand-made doughs, and amounted to 70 quarts per sack.

Nos. 2 and 3 were machine-made in the manner described.

No. 2. Water was taken in the proportion of 66 quarts to the sack. The machine was turned until the flour and water were incorporated: 30 additional revolutions were then given. The dough stood an hour, and was then passed through the viscometer. The time is given below. For gluten and other determinations 31.8 grams of dough were taken at the close of the hour, being equivalent to 20 grams of flour. The water used for washing gluten was reserved and made up to 1,000 c.c. On this solution, the soluble proteins and other soluble matter were determined.

No. 3. Water was again taken in the proportion of 66 quarts to the sack. After incorporation, 250 revolutions were given to the machine. The dough stood one hour, and was then passed through the viscometer. It was then returned to the machine, and received another 250 revolutions. The dough was now very sticky to handle, and was once more tested by the viscometer. It was again returned to the machine and subjected to another 250 revolutions. By this time it was much more sticky, presenting in fact the appearance of bird-lime. The dough could be drawn out into long threads, was very moist, and in fact appeared as though it contained much more water.

The following are the viscometer results:—

	No. 2.	No. 3.
After one hour	873 seconds.	520 seconds.
After another 250 revolutions ..	—	16 „
After a further 250 revolutions ..	—	7 „

In No. 3, compared with No. 2, there is a marked diminution in water absorbing power. But with the further kneading, No. 3 dough became altogether altered in properties, and had in fact entirely lost the characteristics of a bread-making dough.

EFFECT OF MECHANICAL TREATMENT ON DOUGHS.

	No. 1.	No. 2.	No. 3.
Wet Gluten	42.30	37.10	35.45
Ratio of Wet to Dry Gluten	2.8	2.9	3.1
Dry Gluten	15.02	12.70	11.44
Non-protein Matter in Dry Gluten	4.25	1.40	0.92
True Gluten	10.77	11.30	10.52
Gliadin ex Gluten	7.36	7.19	6.24
Glutenin ex Gluten, by difference	3.41	4.11	4.28
Percentages on Dry Gluten.			
Non-protein Matter in Dry Gluten	28.29	11.02	8.04
Gliadin	49.00	56.61	54.54
Glutenin	22.71	32.37	37.42
Total Proteins	12.95	12.95	12.95
Proteins soluble in Water	1.49	1.26	1.56
„ recovered as True Gluten	10.77	11.30	10.52
„ lost in washing Gluten	0.69	0.39	0.87
Gliadin ex Flour	6.43	6.43	6.43
Glutenin ex Flour, by difference	5.03	—	—
Percentages on Total Proteins.			
Proteins soluble in Water	11.50	9.73	12.04
„ recovered as True Gluten	83.16	87.26	81.23
„ lost in washing Gluten	5,34	3.01	6.73
Gliadin ex Flour	49.65	49.65	49.65
Glutenin ex Flour, by difference	38.85	—	—
Non-protein Matter soluble in Water	3.35	5.82	6.00

On making gluten tests, No. 2 yielded less wet and dry gluten than No. 1, but washed quite normally. The true gluten was slightly the higher, showing that the loss in washing was almost entirely non-protein matter. On proceeding to wash gluten from No. 3, the whole dough broke down into a flocculent and non-coherent mass. It was only by pouring this on to a sieve, and collecting by pressing the particles together, that any gluten was recovered. When thus obtained the gluten was soft and flabby and possessed scarcely any coherence or elasticity, whereas those of Nos. 1 and 2 were tough and resilient. Although so profoundly altered in physical character, the chemical composition of the gluten does not show correspondingly great changes, the principal being a diminution in the gliadin, which was estimated by the "starch method." (See Chapter XXIII.) Determinations were made on the collected washing water, but these cannot be regarded as perfectly accurate, since some loss is inevitable. They may, however, be taken as comparative between Nos. 2 and 3. A decidedly greater amount of protein was soluble in water in No. 3 than No. 2. The total loss of protein in washing was also higher, though in none of the experiments was the loss very great. The whole of the results are set out in detail in the preceding table. They go to show that not only is the gluten physically altered, but there is some change also in solubility in various media. In addition to the alteration in the gluten, there is a considerable increase in the amount of soluble non-protein matter.

The interesting point of these experiments is that by simply mechanical attrition of the dough, profound changes are made in the character of the gluten and apparently in the same direction as those which result from treatment with dilute acids as carried out by Wood.

441. Relation of Gliadin Ratio to Strength of Flour.—With Osborne and Voorhees' demonstrations of the insoluble proteins of flour consisting of gliadin and glutenin, a very natural development of inquiry was along the lines foreshadowed in the 1895 edition of this work, and consisting of determinations of the total amount of each of these present in a flour, and the ratio such amounts bore to each other. Guthrie, Fleurent, Snyder, and others have contributed to this research, and each has employed methods of determination more or less original. A consequence is that different proportions of the total protein is returned as gliadin or glutenin according to the process adopted, and as a result differing conclusions have been formed as to the most desirable ratio between these bodies. Guthrie obtained from about 59 to 78 per cent. of gluten as glutenin (which figure also includes the non-proteins.) He concludes that a preponderance of glutenin is preferable, and that increased gliadin produces a weak, sticky, and inelastic gluten. With a totally different method of extraction, Fleurent found his best results with 25 per cent. of glutenin to 75 per cent. of gliadin, and a deterioration with a departure in either direction. Guess extracted his gliadin direct from the flour, and without any limitation found that the more gliadin present, the more elastic and better was the gluten. Snyder places on record that the alcohol-soluble portion of flour protein (gliadin) may vary from as high as 70 to as low as 45 per cent. with only minor variations in the size of the loaf or the bread-making value of the flour. Further he regards gliadin as not being of uniform composition. In Chamberlain's opinion, so-called gliadin contains also albumin and globulin. Wood finds that flours which are at the extreme ends of the scale of strength may have substantially the same proportions of gliadin to total nitrogen. Snyder in fact shows that widely different gliadin contents may occur in practically identical flours: Wood supplements this by showing that widely different flours may be practically identical in their gliadin contents. In other words, glutens containing the same proportions of gliadin and glutenin may be either weak or strong. The natural conclusion is that **strength or weakness is independent of the ratio of gliadin to glutenin in the gluten.** As gluten is not subjected to the solvent action of 70 per cent. alcohol in the process of bread-making, it does not seem that it would necessarily follow that a connexion must as of course exist between the degree of solubility in that reagent and the strength of the flour.

Gluten is probably a loose compound of gliadin and glutenin in varying proportions, and its qualities as a whole, from the bread-making standpoint, are apparently not closely related to its protein composition. For its marked differences in properties, the most likely explanation is that they are based on variations in physical rather than chemical character. This fact has been recognised by Baker and Hulton, who in discussing enzyme action on gluten remark that "the physical character of the gluten may be much modified during the early stages of enzyme action without the production in large quantity of soluble decomposition products. In this connection may be noted the profound change in the viscosity of a starch paste under the influence of a trace of liquefying diastase before any maltose is produced." **Strength, then, must be regarded as depending on the quantity and physical character of the gluten of the flour.**

442. Conditions affecting the Quantity and Physical Character of Gluten.—These naturally constitute the subject of the next line of inquiry. As to quantity, that is largely a question of selection of seed and circumstances of cultivation, and therefore mostly lies outside the scope of the present work. Much careful and successful research has, however, been devoted to such questions as the choice of seed, and effect of soil, climate, and manuring on the development of the gluten content of wheat. But the miller and baker (in those capacities) have only to manipulate and do their best with wheats and flour as they find them. Turning next to the question of physical character and how it may be modified, that also is a problem which largely lies within the domain of the agriculturalist and his advisers rather than the miller and baker. Again, the choice of seed and other factors previously mentioned have a most important bearing on the subject. In particular, the researches of Wood have evidently been conducted with the object of assisting the farmer in growing strong wheats and with a full realisation of limits and possibilities which do not so much concern the subsequent handlers of wheat and flour. Among the factors which have been suggested as modifying agents on gluten are sugar, proteolytic enzymes, acidity and certain mineral salts of the wheat or flour. Sugar has already been discussed, and reference has been made to its power of increasing the proportion of gluten which is soluble in 70 per cent. alcohol. Ford and Guthrie point out that certain flours contain a proteolytic enzyme which has an extremely detrimental effect on the tenacity of the gluten, and described methods by which this body can be detected. Baker and Hulton have also investigated the matter of the presence of proteolysts in flour. They, however, came to the conclusion as far as concerned the flours examined by them, that there was no soluble proteolytic enzyme in flour capable of degrading albumin or gluten with the production of soluble nitrogenous bodies. They find, on the other hand, that the gluten in dough is attacked by yeast enzymes, with an increase in the amount of soluble proteins. It is in this connection that they make the remark before quoted as to the possibility of profound physical changes in gluten, with no (or but little) chemical change. Fermentation, as already shown, may increase the quantity of protein recoverable as gluten; it also possesses the property of materially softening that body, and at the same time increasing the amount of protein which while insoluble in water is soluble in 70 per cent. alcohol. The following results were obtained on a flour by the authors. The percentage of constituents is calculated on the dried solids of the flour, and the fermented dough respectively:—

	Flour.	Fermented Dough.
Dry Gluten	12.14	11.08
True „ (Proteins)	10.33	10.14
Gliadin ex Gluten	2.80	3.20
Glutenin	7.53	6.94
Ratio of Gluten to Gliadin	2.7	2.2

Any reagent or action by which this change is assisted is therefore aiding in the development of the strength of the dough, provided such changes are not thereby carried too far, since the weakness of an overworked dough is probably due to the same causes as those which are beneficial in a lesser degree. Although strength seems independent of the original proportions in which gliadin and glutenin exist in a flour, yet those changes during fermentation which result in increased elasticity of the dough are usually accompanied by an increase in the alcohol-soluble content of the gluten. Both sugar and proteolysts may therefore in this manner exert a beneficial influence on the dough.

Snyder finds that any slight increase of acidity in the grain diminishes the percentage of gliadin (paragraph 426). On the other hand, Wood (paragraph 430), finds acidity to have no relation to strength. Wood states that certain acids in small quantity have a marked disintegrating action on gluten, which effect increases with the degree of acidity, until with further concentration a reverse action occurs, and at a certain point the effect of the acid is to harden the gluten and render it more elastic and coherent than was its original condition. Other acids show no such reverse action, but up to any limit of concentration effect a disintegration which becomes more rapid as the acidity increases. It is difficult to say whether in actual dough fermentation the effect of acid on gluten is in its earlier stages capable of inducing beneficial changes thereon. At the later and overworked stages, the acid developed is probably one of the factors in carrying the changes in gluten to a condition of less gas-retaining power.

443. Effect of Mineral Salts on Gluten.—Wood has made a series of most important investigations as to the effect of certain mineral salts on gluten. His most recent conclusions are embodied in a personal communication from Professor Wood, kindly made for the purposes of this book, and contained in paragraph 433. In determining whether a wheat shall be weak or strong, Wood is of the opinion that the effective action of beneficial salts occurs during the growth of the grain, while the endosperm is being formed and is in a comparatively milky stage. In order to improve wheat at this stage, the salts must evidently be obtained from the soil. Experiments made by Chitty and one of the authors go to show that wheats may be improved in this direction, when in the hands of the miller, by treatment of the grain itself (paragraph 541). Additions to the flour as flour, or at the time of doughing, are also capable of effecting material improvements. Interesting examples of this are the at one time prevalent addition of alum when flours were exceedingly weak, and the bakers's well-known expedient of using an extra quantity of salt with a very weak flour. Though the former addition is condemned on other grounds, it undoubtedly considerably improved the strength of the flour. So, too, salt has a decided "binding" effect on a weak and runny dough. The problem cannot at present be regarded as completely worked out, but the results already obtained, confirmed as they are by practical experience, go to show that **the presence or absence of certain mineral salts is a most important factor in determining the strength or weakness of gluten and consequently of flour.** Bearing in mind that flour of itself is toxic to some varieties of yeast, and that certain mineral salts act as an antidote to the poisonous action, it is of interest to note that some mineral salts increase the strength of gluten. Indirectly they may further benefit the working properties of a flour by nullifying its toxic action to yeast.

444. Gluten Determinations.—From the foregoing expressions of opinion, it will be gathered that the authors continue to attach importance to properly conducted gluten determinations. The estimation of wet gluten is a measure of the amount of that constituent of flour, which by its physical character determines the quality and nature of the resultant dough and bread. It further determines this in a way which is comparatively easy of performance and affords results which are readily understood by all concerned. In the hands of an expert flour valuer, not only the quantity of gluten, but its appearance and general characters give most valuable indications as to the type and quality of a flour, even though they cannot be expressed in percentages or other forms of figures. The following remark of Saunders is an interesting confirmation of the practical value of the gluten test:—"In addition to the final baking tests I have used for several years a simple chewing test (taking only a few kernels of wheat) as a valuable guide to gluten strength and probable baking strength in the earlier stages of selection. This test was advocated as an essential aid in the selection of crossbred varieties of wheat in the Bulletin on Quality in Wheat, published at Ottawa, October, 1907." (*Supplement* 4, June, 1910, *p.* 29, *Jour. Board of Agriculture.*)

CHAPTER XVI.

COMPOSITION AND PROPERTIES OF FLOUR AND OTHER MILLING PRODUCTS.

445. Flour Properties.—Among the general properties of flour, that of Strength has been deemed of sufficient importance to warrant its treatment in a separate chapter. Flour also possesses certain other physical characters of which some explanation must be given. These include Colour and Water-absorbing power. For scientific purposes it is necessary to have not only means of judging and comparing these, but also some method of registering for future reference, and for the institution of comparisons between the results obtained by one observer and those of another. In order to do this, these properties must in some way be expressed numerically.

The whole subject of these various measurements is exhaustively discussed in a subsequent chapter on Flour-Testing, but as in this section a number of analyses are quoted, in which estimations of colour, etc., are inserted, a brief mention is here made of the principle of the method by which these have been judged.

446. Colour.—Every miller and baker will be acquainted with the ordinary method, devised by Pékar, of determining the colour of a sample of flour by compressing a small quantity into a thin cake or slab, which is wetted and allowed to dry. The depth and character of the colour are then observed. This test has been in use for some time, and answers admirably the purpose of comparing the relative colour of two or more samples.

447. Water-Absorbing Power.—The water-absorbing power of a sample of flour is one of the most important properties it possesses, and its determination is of great value to both miller and baker. It not only governs the yield in bread of the sample, but also affords evidence of its other qualities. Hence, water-absorbing determinations are valuable in several respects. Although not always applied in precisely the same sense, for our present purpose, **Water-absorbing power may be defined as the measure of the water-absorbing and retaining power of the flour, or of the water absorbed by the flour in order to produce a dough of definite consistency**: it always being understood that the dough shall be capable of yielding a well-risen and properly cooked loaf without clamminess. The water-absorbing power of the flour from any particular wheat is in practice governed by the way in which it has been treated during milling. Thus an excess of water used in the conditioning process will reveal itself in a deficiency in the water-absorbing capacity of the flour.

448. Composition of Roller Milling Products.—As milling is an art in which the wheat is changed into flour and offal, it is a matter, not only of interest, but of importance, that it should be known what is the constitution of the flour and various other products of milling. The following table is given on the authority of Richardson, Chemist to the Department of Agriculture of the United States Government, who made a most important and exhaustive series of analyses of products of roller milling.

ANALYSES OF THE PRODUCTS OF ROLLER MILLING, BY RICHARDSON.

NAMES.	Water.	Ash.	Oil.	Carbo-hydrates.	Fibre.	Proteins.	Nitrogen.	Phos-phoric Acid.	Ratio Nitrogen to Phos-phoric Acid.	Gluten.	
										Moist	Dry.
C. A. Pillsbury & Co., Minneapolis, Minn.	%	%	%	%	%	%	%	%	%	%	%
Wheat prepared for the rolls	9.07	1.79	2.74	70.37	1.68	14.35	2.30	.82	2.80	32.31	11.88
Bran	10.91	5.59	5.03	56.21	5.98	16.28	2.60	2.78	.94	—	—
Finished flour:											
Bakers'	12.18	.62	2.00	69.99	.33	14.88	2.38	.31	7.68	51.21	16.97
Patent	11.48	.39	1.45	73.55	.18	12.95	2.07	.18	11.50	36.14	10.85
Low grade	12.01	1.99	3.86	63.26	.93	17.95	2.74	1.16	2.36	10.01	4.26
Break flour	12.48	.58	1.87	69.44	.23	15.40	2.46	.31	7.94	51.38	15.87
Stone flour	12.04	.49	1.61	72.85	.23	12.78	2.04	.27	7.55	38.21	11.74
Herr & Cissel, Georgetown, D. C.											
Mixed wheat, clean	9.62	1.93	2.29	71.83	1.55	12.78	2.04	.98	2.08	30.00	11.03
Patent flour	12.98	.32	.92	75.60	.20	9.98	1.60	.16	10.00	29.55	9.08
Bakers' flour	13.29	.47	1.26	72.45	1.50	11.03	1.76	.28	6.28	35.04	11.30
Low grade flour	12.59	1.05	2.33	69.10	.75	14.18	2.27	.58	3.91	35.96	12.81
Warder & Barnett, Springfield, Ohio.											
Wheat	9.05	2.06	2.46	71.67	2.33	12.43	1.99	1.03	1.93	20.93	10.34
Patent flour	12.32	.34	1.05	78.28	.33	10.18	1.71	.19	9.00	35.52	10.76
Bakers' flour	11.98	.60	1.77	71.52	1.00	13.13	2.10	.33	6.36	38.29	12.30
Low grade flour	12.36	.69	1.00	75.04	.93	9.98	1.60	.30	5.33	28.37	9.96
Bran	7.74	6.99	4.99	—	—	15.40	2.46	1.04	2.36	—	—

Richardson selected samples from three mills; the first being from Messrs. Pillsbury's mill at Minneapolis, where a straight run of spring American wheat was used; the second, Messrs. Herr and Cissel's mill, employing soft winter wheat; and the third from the mill of Messrs. Warder and Barnett, of Ohio, using all red winter wheat.

449. Damping Wheats.—It is the custom of millers to add to some of the harder and more flinty wheats, particularly those of India, more or less water as a preliminary to milling. The addition of such water is generally supposed to have two effects, the first being a softening of the bran, and the second an increased yield of flour. The softening of the bran renders it less brittle, and so less gets broken up, and thus into the flour.

It is essentially a question for the miller, rather than the chemist, to decide whether the damping of Indian wheats renders them more workable and amenable to milling processes generally. It is quite conceivable that a "mellow" wheat is more easily converted into flour than one which is hard and brittle; but, against any consideration of ease in milling must be set the effect, if any, of damping on the after quality of the flour produced.

In connection with this subject the authors have analysed a number of samples of Indian and other hard wheats, dry and damped, and also the flours produced therefrom. The following are the general conclusions derived from an extended and exhaustive series of experiments:—

In artificially damping wheats, but a small proportion of the water finds its way into the flour. The actual amount varied from 3.8 to 17.1 per cent. of the total quantity added. This depends on the length of time allowed to elapse before grinding. The water penetrates evenly through hard Indian wheats in about forty-eight hours.

The addition of water to wheats already containing an average quantity of water (in experiment cited, 13.2 per cent.) is decidedly deleterious; strength and colour are both injuriously affected. But this will depend somewhat on the nature of the wheats. Thus some Indians may be damped to contain 15 per cent. of moisture, while Russian wheats should be restricted to a limit of 13 per cent.

With wheats in a dry state (11.0 to 11.5 per cent. of water) damping in a slight degree does not seriously affect the colour or strength of the flour.

On making baking tests with the flours from such slightly damped wheats compared with those of the wheats milled dry, the damped wheat flours fall off less during fermentation, yield bread of better colour and flavour, and in practically the same quantity.

The slight damping of the very dry wheats enables the miller to produce a better quality of flour.

450. Washing Wheats.—In view of the growing importance attached by millers to rigidly clean flours, and the consequent necessity for the removal of the dirt and other impurities often associated with wheat; the grain, and especially the more dirty varieties, is now thoroughly washed before being milled. Although Indian and the more flinty types of wheat bear a prolonged submergence in water, the softer kinds of grain are injured by any but the shortest washing process. The modern washing machines are therefore not intended to soak wheat, but to wash it clean from extraneous dirt as rapidly as possible. The grain is then dried by treatment in a centrifugal machine, or "whizzer." This operation not only frees the wheat from ordinary dirt, but also largely removes bacteriological impurities which may be of an objectionable nature.

The question frequently arises, what kind of water is fit for wheat washing purposes? The quantity used is large, amounting sometimes to as much as 20 gallons per bushel of grain washed per hour. Thus to wash 100 bushels of wheat hourly, in extreme cases, 2,000 gallons of water per hour may be required. The purchase of water of drinking quality for this purpose is very expensive, and may even in some places be prohibitive. Millers are consequently compelled to seek some other source of washing water if possible. Among these, sea-water, if free from contamination, is employed, or river water is frequently used. The latter may of course be of almost any degree of purity. There is little doubt that the standard of purity for this purpose need not necessarily be so high as that required in water for drinking purposes. But taking a filtered river water which yields on analysis—

Nitrogen as Free Ammonia	14 parts per 100,000
Nitrogen as Albuminoid Ammonia ..	5 „ „ „

may it be used or not for wheat washing?

It need scarcely be pointed out that these data entirely condemn the water for drinking purposes. But in rapid washing as distinct from soaking, the exposure to the water is only for a very short period of time. In some experiments made, in which wheat was subjected to more prolonged treatment with water than occurs in the mill, it was found that the resultant flour had its moisture raised from 13.2 to 13.7 per cent., being an absorption of 0.5 per cent. of the weight of the flour. In washing, therefore, but very little water is absorbed by the grain, and of that little by far the greater part does not penetrate beyond the bran and into the flour. Corroboration of this is afforded by washing with sea-water; the flour is not perceptibly rendered salt, and the bran is eaten and keenly relished by animals. In event of the washing water containing bacteria, there may be some apprehension of these finding their way into the flour. But although they may possibly find a lodgment on the outer skin of the bran, in practice there is no contamination of any of the flour, except possibly the very last reductions from the bran. Unwashed wheats will usually contain more bacteria than any water used for washing, and consequently are rendered bacteriologically cleaner by washing with any ordinary water. Further, washing with an abundance of a slightly impure water will produce a cleaner wheat than is obtained by the use of a purer water in stinted quantity. Naturally the washing water should be as clean as practicable, and of a good quality; but it is not necessary that it be judged by the same standard of purity as is required of a drinking water. Where the washing water is of the ordinary river type, a good plan is to use an abundance of this to remove the bulk of the dirt and then to give a final rinsing with a small quantity of clean water.

451. The Germ.—This most interesting body differs remarkably in composition from the other parts of the grain. The percentage of contained water is somewhat low, but the soluble extract is remarkably high, amounting to just one third of the whole of the body as removed in the modern processes of roller milling. Of the soluble extract, 15.51 per cent. consists of proteins. There is no gluten recoverable. The ash and phosphoric acid are high; the fat also is much higher than in any other part of the grain, amounting to from 12 to 15.6 per cent. The cellulose is moderately high.

Detailed analyses of germ have been made from time to time; there follow results of such analyses made respectively by Richardson, Teller, and one of the authors.

ANALYSES OF GERM.

	Richardson.		Teller.		Jago.	
	Per ct.	Per ct.		Per ct.		Per ct.
Water	—	8.75		6.80		13.23
Ash	—	5.45		4.65		4.94
Oil	—	15.51		14.38		12.03
Soluble in 80 per cent. alcohol	26.45	—		—		—
Insoluble in water	—	1.98		—	Dextrin	1.24
Soluble in water	25.47	—		—	Maltose	5.54
Sugar or Dextrin	—	18.85		—		—
Non-reducing substance	—	2.94		—		—
Proteins	—	3.65		—		—
Soluble in water	4.44	—		—		—
Dextrin	—	1.44		—		—
Proteins	—	3.00		—		—
Starch, etc, undetermined	—	9.95		1.60		33.78
Cellulose	—	1.75	Proteins	39.62	Sol. proteins	15.51
Insoluble Proteins	—	26.60	Carbo-hydrates	32.95	Insol. proteins	13.73
		100.00		100.00		100.00

Osborne and Campbell find that germ contains a *nucleic acid* in considerable quantity, and having the following composition:—

Carbon	36.48
Hydrogen	4.48
Nitrogen	16.17
Phosphorus	8.96
Oxygen	33.91
	100.00

There are also present the following proteins—leucosin, a globulin, (contains only two kinds of the sulphur of edestin) and a proteose. (*Jour. Amer. Chem. Soc.*, 1900, 379.)

As one of the objects of modern milling is to thoroughly remove the germ from flour, the actual effiect produced by germ, when present, is a subject of great importance. An account of some experiments on mixtures of germ and flour is given later in this chapter.

452. Effect of the Germ on Flour.—One of the questions which for a considerable time has occupied the attention of the milling world, is whether or not the removal of the germ affects the flour injuriously or otherwise. Among the various authorities on this point, Graham, Richardson, and others, are unanimous in expressing a strong opinion in favour of its removal. Briefly stated, the reasons that render this course advisable are that the presence of the germ discolours the flour, and also, as a result of its high percentage of fat, gives it a decided tendency to become rancid. In addition, the germ exerts a marked diastatic action on the imperfectly matured starch of slightly unsound flours. On the other hand, the advocates for the retention of the germ assert that it renders the flour sweeter, and also causes the bread to have a pleasant moistness on the palate. Under any circumstances these results are not likely to be attained except by using the flour immediately it is milled; this is frequently impossible, and even then the baker must be prepared to face all those difficulties caused by the presence of an undue quantity of active diastatic agents in the sponge and dough. Milling experiments on a large scale have been made on the germy semolina produced during gradual reduction. Such semolina, on being reduced on stones, yields a dark coloured unsatisfactory flour, which produces a low quality bread. On rolling and repurifying these semolinas, the resulting flour is of good colour, and yields bread of high quality. So far, these experiments afford evidence directly in favour of the removal of the germ. An extensive series of experiments made by one of the authors, and previously published, prove most conclusively the ill effects resulting from the admixture of germ with flour.

Typical Flours and their Characters.

Name.	Moisture.	Dry Gluten.	Water absorbed, Quarts per Sack.	GENERAL CHARACTERISTICS.
Spring American patent..	12.60	13.42	71.0	Hard dry flours, containing a high proportion of very elastic gluten, which only slowly softens during fermentation. Water-absorbing power high; colour good, but white, with comparatively little yellow or bloom in the bread. Loaf very bold and of good texture; crust yellow without foxiness; will bear very hot oven. Bread tends somewhat rapidly to become hard and dry, and is comparatively flavourless. A doughing flour, but it may be used in rapid sponges, or one-third in long sponges.
Spring American bakers'..	13.16	14.54	73.0	Also hard and dry, higher proportion of gluten, but usually somewhat less elastic; softens very slowly. Water absorbed rather higher than with the patent; colour dark and greyish, varies with different brands. Loaf bold but textureless, crust very foxy, catches readily in the oven. Bread harsh and dry; has, with samples of specially low grade, a strong beany flavour. Straights and bakers' grades are good sponging flours, not good doughing flours.
Canadian hard Fyfe wheat patent	12.90	10.8	82.0	Very much the same characteristics as the spring American patent, but has remarkably high water-absorbing capacity. A sponging and doughing flour, but neither straights nor bakers' grades from this wheat are good doughing flours.
Winter American patent..	11.66	8.26	65.0	Comparatively soft flours, containing a moderate proportion of gluten, which softens more rapidly during fermentation than the preceding, but still is fairly tough and elastic. Absorb medium quantity of water. Colour is very good, white and more bloomy than the spring American. Makes a very good loaf by itself, quite of medium size, and fair texture. Good yellow crust without foxiness. Bread fairly moist and pleasant in flavour. Doughing flours all grades, but may be used for rapid sponges, taken on the first turn.
Winter American bakers'..	11.73	10.1	69.0	Similar on the whole to the patents in general properties. Some brands make doughs with little elasticity, but which hold up well and do not give during fermentation. Loaf not up to medium size, low, and with rather a tendency to run. Much less foxy crust than spring American, of about same grade, also better colour in crumb. Flavour moderate, and usually devoid of any harshness. Bread sometimes clammy.
Kansas hard winter patent.	12.45	13.5	73.0	The hard winter wheat flours of Kansas are very similar in character to the spring American flours of Minnesota. The gluten runs fully as high, but is rather softer, and softens more rapidly during fermentation than the spring Americans. The colour is generally good, in many samples being marked by a much fuller yellowness than is the spring American patent. Flavour is usually good, and bread fairly moist. May be used for sponging, and also answer well as doughing flours for mixing with very weak, flavoury varieties.
Californian straight grade.	12.1	7.13	64.0	These are usually weak, dry flours, with comparatively little gluten. They are of good colour, full yellow, and sweet in flavour.

TYPICAL FLOURS AND THEIR CHARACTERS—*Continued.*

Name.	Moisture.	Dry Gluten.	Water absorbed, Quarts per Sack.	GENERAL CHARACTERISTICS.
Kubanka (Russian).......	10.90	16.06	.....	Hard, dry flour, with unusually high percentage of gluten; makes a big loaf. Colour very yellow, almost pea shade; bakes very foxy. Bread very harsh and coarse in flavour. Sponging—long sponges—not good doughing flour.
Azima (Russian) straight grade	12.36	12.70	71.5	Hard flours, with good percentage of gluten, but soften more readily during fermentation than spring American grades, for which these flours make useful substitutes. Colour of patents good; rather more tendency to foxiness than the American. Loaf bold, but if the dough is permitted to lie, frequently shows tendency to run. Bread comparatively flavourless; in lower grades coarse in flavour. Sponging flours; the patent grade may be used, one-third in sponge and one-third in dough.
Hungarian best patent...	10.82	10.48	76.0	Dry and comparatively soft flours; only medium percentage of gluten, which is very soft but elastic. Water-absorbing power remarkably high; colour white, with a most delicate shade of bloomy yellow. Loaf not very large, but of peculiar silky texture; crust yellow without foxiness. Bread moist and of exquisitely delicate flavour. Doughing flours, but may be used in rapid sponges taken on the first turn.
Hungarian lower class patents	10.98	9.23	74.5	Flours with less gluten and lower water-absorbing power than the higher class patents. Colour very good, but usually full yellow. Bread moist, and somewhat liable to be clammy.
No. 2 Calcutta flour......	12.60	9.68	71.5	Indian flours generally are hard flours of a ricy character. Their gluten is low in amount, and usually very deficient in elasticity. The quality of water absorbed is high. Colour is low, except with very great milling precautions. Loaf is small and runny, devoid of texture, and foxy. Bread is harsh and beany in flavour.
Old white English wheat flour	14.00	9.82	62.0	Flours from English wheats are usually soft and damp. Very considerably with change of climate and locality. Proportion of gluten low and devoid of much elasticity. Water-absorbing power low. Patent flours are of very good colour and bloomy; bakers' grades dark and grey. Loaf small and compact; crust of better class of flours free from foxiness. Bread is moist, and has a very sweet, nutty flavour. Doughing flours of all grades; may be used alone, doughing direct.
Flour from kiln-dried Scotch wheat	13.80	7.94	63.0	Scotch flours are even moister and softer than those from English wheats. Like them, they are low in gluten and water-absorbing capacity. Loaf is small, bread moist, and flavour pleasant. Doughing flours all grades; may be used alone, doughing direct.
French flour.............	.....	10.31	61.6	French flours have been again placed on the English markets. They are below the average of English milled flours, of the same price, in strength and water-absorbing power, but in most cases possess good colour and flavour.

453. Fatty Matters and Acidity of Flours.—Balland has made a series of determinations of these with the following results:—

Wheat germs mixed with bran from a recent milling.—The fatty matter extracted by ether contained about 83.34 per cent. of a fluid oil, and 16.66 per cent. of solid fatty acids. The original substance also contained other acids insoluble in ether.

Flour from soft wheat, for army rations, from an old milling.—The fatty matters contained about 18 per cent. of a very fluid oil, and 82 per cent. of mixed fatty acids. The acidity of the flour was due to several acids, some soluble in water, alcohol, and ether, and others insoluble in water and in ether.

Flour from hard wheat, for army rations, from an old milling.—The fatty matters were composed entirely of free fatty acids, which hindered the hydration and extraction of the gluten. Balland deduces the following *general conclusions*:—The fatty matters of freshly milled flour consist of a very fluid oil and solid fatty acids of different melting points. In course of time the oil, which is very abundant at first, gradually diminishes and disappears, with a corresponding increase of the fatty acids, so that the ratio of oil to fatty acids is a measure of the age of the flour. The fatty acids themselves disappear in time and are not found in very old flours. The conversion of the oil into fatty acids is not limited to the flour only, it takes place also in the products isolated by ether. The acidity, which is the first indication of alteration of the flour, is not connected with the bacterial decomposition of the gluten, but is derived directly from the fat. The gluten is not attacked until the fatty acids produced from the oil begin to disappear. The richer the flour is in oil, the more liable it is to alteration—as, for instance, flour from hard wheat. In order to have a flour which will keep well, it is advisable to select a soft wheat with a low percentage of fat. (*Comptes rend.*, 1903, **137**, 724.)

454. Distribution of Gluten in Wheat.—Considerable interest attaches to the relative proportions of gluten in the flours produced during the different operations of gradual reduction. Closely connected with this question is that of the distribution of gluten in the wheat grain. A number of writers on wheat make the statement that gluten is found almost, if not quite, exclusively in the inner layer of the bran; and that it constitutes the contents of those cuboidal cells seen so prominently in the inner layer of bran when microscopically examined. These cells are even now frequently termed ''gluten cells'' from this supposed property. The bran of wheat contains, however, no gluten whatever, the whole of that body being derived from the contents of the endosperm. Hence it follows that flour contains more gluten than does whole wheat meal.

455. Baking Characteristics of Typical Flours.—The tables on pages 296 and 297 record not only the gluten and other determinations in certain typical flours, but also contain a statement of their general baking characteristics.

456. Seasonal Variations in Flours.—Balland arrived at the following conclusions from the analysis of 2,500 samples of flour analysed in the Laboratory of the French War Department between September, 1891, and June, 1894. He finds the water to vary from 9.40 to 16.20, being at a maximum in February and a minimum in August. The lowest percentage of acid found by him was 0.013 per cent. in January, while samples examined in August contained as much as 0.037. From this he draws the conclusion that flours for long storage should be made and packed in dry cold weather. The moisture present in wet glutens is found to vary from 52 to 71.3 per cent.; that in the best flours for bread-making being about 70 as against 62 to 65 in those of medium quality. As the acidity of the flour increases the percentage of water in the wet gluten diminishes. None of these flours contained either foreign mineral matter or farinaceous substances as adulterants. (*Comptes Rend.*, **119**, 565.)

457. **Preservation of Flour by Cold.**—Balland finds that flour stored for three years in a vessel maintained at a temperature ranging between — 2 and + 2° C. underwent very little change. The sample was somewhat tasteless, a result probably of moisture in the apparatus. The amount of gluten had slightly increased, as compared with a test on the new flour; it was homogeneous, sweet, and contained 71 per cent. of water. The fatty matters and acids were present in the same quantities as in the original flour. (*Comptes Rend.*, 1904, **139**, 473.)

The Bleaching of Flour.—Attention has recently been directed to the possibility of removing more or less of its natural colour from flour; and this problem has been made the subject of much investigation.

458. **Sources of Colour in Flour.**—The following may be taken as a classification of the nature and sources of the colouring matter present in flour.

1. *Bran.*—The outer envelope of the wheat grain is from a pale yellow to a reddish-brown tint, and contains large quantities of colouring matter. If finely ground bran finds its way into flour, the particles impart their own tint to the flour, and when made into bread this colour is intensified by being dissolved and permeating the whole of the substance of the bread.

2. *Crease and other Dirt.*—Outside dirt, especially that of the crease of the grain, may be ground up into the flour, and will thus give it a sad, bluish-grey tint.

3. *Colouring Matter of Endosperm.*—In some wheats the whole endosperm is more or less coloured yellow. A notable instance of these is Walla Walla wheat of Oregon (before referred to), which yields a flour sometimes as yellow as a primrose.

REMOVAL OF COLOUR.

1. *Bran.*—This is now removed by careful milling and purification from all small bran particles.

2. *Crease Dirt.*—To get rid of this and other outside dirt, the grain is thoroughly scoured and polished in the dry state, or washed and dried. Further, the grains are in the first operations of milling carefully split longitudinally along the crease, and the dust lodged therein got rid of before any further reduction of the broken grain into flour.

Note.—Regarding the flour as consisting only of the endosperm of the grain (or, as it is sometimes called, the kernel or the berry), ground into a fine powder, the removal of bran and crease dirt is only a removal of foreign substances, and a consequent purification of the flour.

3. *Colouring Matter of Endosperm.*—This evidently stands in a different category, because it is the colour of the flour itself, and not that of any foreign matter, even from other parts of the grain.

This colouring matter is somewhat unstable in character, as it diminishes very noticeably on keeping flour some two or three months, and also varies considerably in different flours.

459. **Flour Bleaching, Snyder.**—A very systematic exposition of the whole subject of flour bleaching is contained in a bulletin issued by the University of Minnesota in 1908. The writer, Snyder, regards the bleaching of flour as a natural process, and introduces his subject by a reference to—

The Colouring Material of Flour.—The composition of the colouring matter of wheat has never been determined, because it cannot be separated in a pure state from the fat and gluten with which it is mechanically associated. It is soluble in ether, and in flour analyses it forms one of the well known impurities of the "ether extract" or "crude fat." When the gluten is obtained mechanically, by washing the dough, it is tinged yellow with the natural colouring matter of the flour.

Avery has suggested that the colouring matter of flour is a nitrogenous compound containing an amino radical. In Bulletin No. 85 of this station it was suggested that the colouring matter was a nitrogenous compound. Other investigators believe it is a non-nitrogenous body akin to xanthophyll and carotin, the natural yellow pigments of plants. It has certain characteristics of carotin as capability of being decolourised by heat, light and chemical reagents. Whatever the composition of the colouring matter of wheat may prove to be it is not a stable compound. After flour has undergone natural bleaching various tints and shades of colour are developed, particularly of grey and light yellow. These various shades and tints may serve as an index of bread-making value, but it is not possible from the colour alone of either freshly milled or cured flour to determine bread-making value. Flours that are pure white, or tinged slightly yellow, have the highest bread-making value. A dark grey or slaty colour is usually an index of poor bread-making qualities. Flours of poor colour when milled, often develop even more undesirable tints by storage. If the flours are not well milled the branny particles become discoloured through oxidation of the cellulose and the flours then show black specks. Hence it is that only well-milled flours from sound wheat are capable of being improved by storage.

Bleaching Agents.—Of the various methods proposed for the bleaching of flour practically the only one that has survived the experimental stage is the nitrogen peroxide process, in which the bleaching reagent is produced directly from the union of the nitrogen and oxygen of the air by electrical action.

In the bleaching of flour the unstable yellow colouring matter is acted upon by the nitrogen peroxide, and from a study of the properties of nitrogen peroxide it would appear to be an oxidation change. As will be shown later, this change, if it be oxidation, does not extend to the other constituents of the flour as fat and gluten, inasmuch as flour bleaching as now practised leaves these and other constituents unaltered as far as chemical tests are capable of determining. As a result of the nitrogen peroxide treatment, some nitrogen trioxide reacting material is left in the flour. For convenience it is assumed to be a nitrite, but cannot be a mineral nitrite like that of potassium or sodium, as it has entirely different properties. That the material is present largely in physical form can be shown by heating bleached flour to a temperature of 95° C. The flour will then be found free from nitrite reacting material provided it has been heated out of contact with a gas flame or combustion products that yield nitrites, or the flour was made from wheat free from mineral nitrates or nitrites.

Fat of Bleached and Unbleached Flour.—When the fat of flour is obtained by the official method of analysis, the colouring matter, lecithin, chlorophyll residue products and other substances are recovered as mechanical impurities mixed with the fat. The chemist uses the term "crude fat" or "ether extract" because of these known impurities. Some of the impurities are nitrogenous and some are non-nitrogenous compounds. Hence any change produced by bleaching in the colour of the fat cannot be said to denote change in the composition, when it is known that the colour is one of the impurities of the fat.

In the bleaching of flour it has been suggested that a slight oxidation of the fat is one of the possible chemical changes which may occur, since nitrogen peroxide, a carrier of atmospheric oxygen, is employed. Should any appreciable oxidation of the fat take place during bleaching, the fat of the bleached flour would have different properties from that of the unbleached flour. Any such change in the fat would necessarily affect such determinations as those of the iodine absorption number and the heat of combustion. Four typical samples of flour (two bleached and two unbleached) were selected for the purpose of extracting the fat in quantity. The flours were dried in such a way as to prevent oxidation, and the iodine number was determined. The following results were obtained:—

	Iodine Absorption Number
Patent flour, unbleached, No. 1	102.9
Same flour, bleached, No. 2	103.7
Patent flour, unbleached	101.1
Same flour, bleached	102.6

Practically no greater differences were observed between the fat of the bleached and unbleached flours than between duplicate analyses of the same sample. As far as the iodine number of the fat is concerned no appreciable difference was observed between those of the bleached and unbleached flours.

It has been suggested that the nitrogen peroxide chemically unites with the fat, resulting in the production of nitrogenous compounds. Should any such change occur it would affect the nitrogen content of the product, and the fat from the bleached flour should show a higher nitrogen content. A number of investigators have shown that lecithin, a nitrogenous compound soluble in ether, is present as an impurity in the ether extract or crude fat obtained in the analysis of flour. Hence it is, wheat fat as ordinarily obtained contains nitrogenous compounds, rendering it exceedingly difficult if not impossible to separate from that naturally present any new nitrogenous compound that may possibly be formed during the process of bleaching. The ether extract or crude fat of three samples of unbleached flour was obtained in quantity by extraction with one of the best grades of commercial ether. Also the ether was purified as directed in the official method of analysis and the nitrogen content of the crude fat extracted with the purified ether by the official method was determined.

NITROGEN CONTENT OF FAT OF UNBLEACHED FLOURS.

Sample.	Commercial Ether.	Purified Ether.
1	0.887	0.873
2	0.919	0.901
3	0.931	0.942

It is to be noted that approximately 0.9 per cent. of nitrogen was found present as a natural constituent of wheat fat. There was no difference in the results whether the ordinary or the modified Kjeldahl method was used for determining the nitrogen content of the fat. In determinations (qualitative or quantitative) of the nitrogen content of the fat of bleached flour, the nitrogen that is naturally present must be recognised, and the presence of nitrogenous compounds in the fat cannot be ascribed to bleaching. The nitrogen content of the fat of three samples of flour before and after bleaching was determined with the following results:—

	Nitrogen of Fat. Bleached.	Nitrogen of Fat. Unbleached.
Flour A	0.866	0.887
Flour B	0.930	0.919
Flour C	0.927	0.931

Duplicate determinations were made and no greater differences in the nitrogen content of the fats from bleached and unbleached flours were found than between duplicate analyses of the same sample. The quantitative determinations of nitrogen showed the bleaching of the flour did not increase the nitrogen content of the fat.

The heat of combustion of the fats was also determined in a Berthelot calorimeter and practically the same caloric value was obtained for the fat from the bleached as from the unbleached flour. The differences in the heats of combustion were no greater than in the case of duplicate determinations on the same sample. If any oxidation or nitration had taken place during the process of electrical bleaching, it would have manifested itself in lowering the heat of combustion. Neither the iodine number, nitrogen content, nor heat of combustion shows any change to have occurred, or that the fats from bleached and unbleached flours differ.

The Glutens of Bleached and Unbleached Flours.—Snyder finds the gluten of flour to be unchanged by the act of bleaching, except in the direction of colour. He further finds that the quantity and composition of the gliadin is unaffected by the bleaching process.

It would not be possible for nitro- or nitrosyl-compounds to be formed during bleaching, because not enough nitrite or nitrate reacting materials are present to permit such reactions taking place. Furthermore nitrous and nitric acids, if present in sufficient amounts to cause a reaction, would produce yellow coloured products in accord with the well known xantho-protein reaction of Fourcroy and Vanquelin, and consequently the flour would have a yellow tint. Such a procedure would be directly opposite to bleaching, and in that event the nitrogen peroxide would act as a stain and not as a decolourising reagent. The trace of nitrogen peroxide employed in the bleaching of flour cannot be regarded in any way as a dye or stain, as it does not unite chemically with either the fat or the gluten, or form a coating over the surface of the flour particles. Its action upon the colouring matter of flour is similar to the change that takes place naturally when flour is cured and bleached by storage.

Physical Absorption of Gas by Flour.—Since analyses of the fat and gluten of bleached flour indicated that no chemical combination had taken place with the trace of nitrogen peroxide used in the bleaching mixture, experiments were undertaken to determine whether the nitrite reacting material in the bleaching gas could all be accounted for as absorbed in the flour. From these experiments Snyder arrived at the following conclusion. The nitrite reacting material in flour appears to be in physical rather than chemical combination. When the flour is heated, the nitrite reacting material imparted by bleaching is expelled. All of the nitrite reacting material in the gas employed for bleaching can be accounted for as soluble and volatile nitrites in the flour and in the air surrounding the flour, leaving no nitrite reacting material to chemically combine with the fat or gluten. When the bleaching gas was brought in contact with pure sand, with which it cannot unite chemically, the same amounts of nitrites were absorbed as in the case of flour.

Loss of Nitrites in Bread-Making.—Bread made from bleached flours containing 0.00004 per cent. nitrogen as nitrites and baked out of contact with combustion of gases gives no reaction for nitrites. Bread made from unbleached flour and baked in a gas oven in which there is direct connection between the combustion chamber and the oven shows appreciable amounts of nitrites formed from combustion of the gas. When the bread was properly made and baked in an electric oven there was no reaction for nitrites from either the bleached or unbleached flours, that is provided the flour itself was free from nitrite and nitrate reacting material except that imparted by the bleaching gas. Snyder regards the nitrite of bleached flour as being more probably ammonium nitrite than that of either sodium or potassium.

Influence of Bleaching of Flour upon the Digestibility of Bread.—In order to determine the influence which commercially bleached flour may exert upon the digestibility of bread a series of digestion experiments was undertaken to determine the digestibility of bread made from bleached and unbleached flour milled from the same wheat. In all, fifteen digestion experiments with men were made. The ration consisted of bread and milk and the general plan of the experiments was as follows. Samples of bleached and unbleached flours and of the wheat from which the flours were made were drawn from a large commercial mill. Digestion experiments were made with bread baked from the bleached and the unbleached flours. Some of the wheat was then milled in the experimental mill of the Minnesota Experiment Station. One-half of the flour was bleached, and digestion experiments were made with bread from this bleached and unbleached flour prepared under chemical control. The results of these five series of digestion experiments are given in the table on page 304.

In one of the trials or series, the nutrients of the bread made from the unbleached flour were found to have a slightly higher digestibility than the bread made from the same flour that had been bleached, while in another series the bread from the bleached flour was somewhat more completely digested. The difference in digestibility of the nutrients of the bread made from the bleached and unbleached flours was too small to be attributed to the treatment the flour had received. The average of the two series shows the bread made from both the bleached and the unbleached flours to have the same degree of digestibility, and that the process of bleaching had no influence upon the digestibility or nutritive quality of the flour. The bread for these experiments was baked in an ordinary cook stove heated by coal, and all the products of combustion of the fuel were excluded from the baking chamber. The bread both from the bleached and unbleached flour gave no reaction for nitrites, the nitrous acid products formed during the bleaching of the flour, and present to the extent of 0.00004 gram of nitrogen determined as nitrites per 100 grams of flour, being entirely dispelled during the process of baking.

Digestion Experiments with Pepsin Solution.—Digestion trials were made with bleached and unbleached flours in acid pepsin solution. The flours used contained 2.04 per cent. nitrogen. The insoluble nitrogen obtained after digestion with pepsin was found to be as follows:—

Trial No.	Bleached Flour. Per cent.	Unbleached Flour. Per cent.
1	0.392	0.378
2	0.343	0.356
Average	0.367	0.367

It is to be noted that the differences between the duplicate trials of the same sample are as great as between the two samples of flour tested.

DIGESTIBILITY OF NUTRIENTS.

	Protein per cent.	Carbohydrates per cent.	Available Calories.
Trial I. Bread from Bleached Flour.			
Man 1	85.74	96.96	91.67
Man 2	84.53	97.52	90.62
Man 3	84.96	97.28	90.35
Average	85.08	97.25	90.88
Trial II. Bread from Unbleached Flour.			
Man 1	86.97	98.47	91.46
Man 2	87.93	98.14	90.89
Man 3	87.63	98.28	91.35
Average	87.51	98.29	91.23
Trial III. Bread from Unbleached Flour.			
Man 1	91.76	99.02	93.87
Man 2	92.14	98.08	94.97
Man 3	91.67	99.08	95.09
Average	91.86	98.73	94.64
Trial IV. Bread made from Bleached Flour.			
Man 1	92.04	99.07	94.41
Man 2	93.24	98.89	95.49
Man 3	93.00	98.88	95.66
Average	92.76	98.95	95.19
Trial V. Bread from Unbleached Flour with Nitrites.			
Man 1	93.56	99.14	95.21
Man 2	93.98	99.19	95.76
Man 3	95.96	99.18	—
Average	94.50	99.17	95.43

As far as digestibility in the acid pepsin solution was concerned no difference whatever was found in the digestibility of the bleached and the unbleached flours.

Are Flours Bleached with Minute Amounts of Nitrogen Peroxide Injurious to Health?—This is a question that can well be raised, because if the bleaching leaves any material in the bread that is injurious to health the practice should be discontinued and condemned. The form in which the flour is consumed as food, or the finished food product, is what should be considered in answering this question. Flour is never eaten in the raw state, but in the process of bread-making, cake-making, and indeed in all the various ways it is prepared for food it is always subjected to the action of heat. As previously stated, when flour is warmed out of contact with combustion gases the nitrite reacting material imparted during bleaching is removed, and the bread and other articles made from the flour give no reaction for nitrites imparted by the bleaching gas. Since the material used in the bleaching of flour is expelled in the preparation of the food, there remains no question for physiological consideration. But since breads made from bleached and unbleached flour give practically like amounts of nitrite reacting material when baked in gas, gasoline or kerosene ovens, it would seem that the broader question could well be raised: is the use of gas and liquid fuels for the preparation of foods, where the food comes in direct contact with the products of combustion, injurious to health? This broader question lies outside the province of the chemist, and also the scope of the present work. Snyder, however, points out that when breathing the air of a room it not infrequently happens that a person inhales during a day more nitrogen trioxide than is present in a pound of bleached flour in the raw state. He further points out that various other articles of food contain nitrites in considerably greater quantity than does bleached flour. If the presence of nitrites generally in these minute traces is to be regarded as injurious to health, then the national food *menu* must be materially curtailed.

Use of Chemicals in Preparation of Foods.—The principle of the use of chemical reagents in the manufacture and refining of foods is recognised in the rules and regulations for the enforcement of the National Food and Drugs Act. Circular No. 21, U. S. Department of Agriculture, Office of the Secretary, Regulation No. 11, states: "Substances properly used in the preparation of food products for clarifying or refining and eliminated in further process of manufacture" are exempt. There is no substance or material used in the manufacture of food products that is as completely eliminated from the finished product (bread) as is the nitrogen peroxide and its products, used in the bleaching or refining of flour. In the manufacture of sugar, sulphur in the form of sulphur dioxide gas is used for bleaching purposes. Lime is employed later in the process for neutralising the sulphurous and sulphuric acids formed and for producing insoluble products which are later removed by filtration. The last traces of the sulphur, however, are not entirely removed, and careful analysis of commercial samples of granulated sugar after combustion in a calorimeter have shown .0098 per cent. of total sulphur. On a percentage basis this is nearly fifty times more than the total nitrate and nitrite products retained in flour, bleached by the use of nitrogen peroxide. Furthermore sugar is used directly as food without any of the sulphur being volatilised. Notwithstanding the presence of this trace of sulphur, granulated sugar is practically pure, as it is unacted upon by the sulphur. The sulphur acts only upon the colouring matter and not upon the sugar. However, a much larger amount of it is used than of nitrogen peroxide in the bleaching of flour. With large amounts of sulphurous and sulphuric acid, chemical reaction takes place with sugar, but the little used as a bleaching reagent fails to produce such a change. In the same way the small amount of nitrogen peroxide used in flour bleaching acts upon the colouring matter of the flour without uniting with any of its constituents. A large amount of gas, however, would produce chemical changes, as would a large amount of sulphur dioxide acting upon granulated sugar. Sugar is a food consisting of only one nutrient. In order to refine and improve it the colouring matter is removed by bleaching. This bleaching is done without affecting the composition. Flour is a food consisting of several nutrients, and the colouring material is bleached by a trace of nitrogen peroxide, without otherwise affecting the composition. Snyder concludes his paper by the statement that in bread-making tests of commercially bleached flours no difference whatever was observed between the breads produced from the bleached and the unbleached flours milled from the same wheats, except that the bleached flours produced a whiter bread and also showed a tendency to produce larger sized loaves. Bleaching of the flour did not impart any odour or taste to the bread or leave in it any residue.

The bleaching of flour enables the miller to manufacture a more uniform product and to place his flour directly on the market without necessitating its undergoing bleaching and curing in storage. No difference whatever was observed between the naturally bleached flours and those bleached by the electrical process except that the latter contained traces of nitrite reacting materials which were expelled during bread-making. (*University of Minnesota Agric. Expt. Station. Bull.*, No. 111).

460. Bleached Flour, U.S. Board of Food Inspection Decision.—By their decision, No. 100, the United States Board of Food Inspection have given it as their unanimous opinion that flour bleached with nitrogen peroxide is an adulterated product under the Food and Drugs Act, 1906; and also that no statement on the label can bring such bleached flour within the law, and that such flour cannot legally be made or sold in the District of Columbia or in the Territories, or be transported or sold in interstate commerce. (*Jour. Soc. Chem. Ind.*, 1909, 157).

461. Decision of English Law Courts.—An action was brought in March, 1909, in the Chancery Division of the High Court of Justice, England, before Mr. Justice Warrington, in which it was alleged by the defendants that the baking qualities of bread made from bleached flour were not improved, that such bread was less digestible, and that the treated flour was deteriorated by the introduction or formation therein of a toxic poisonous substance. In giving judgment, Mr. Justice Warrington concluded by saying: "It seems to me, therefore, that, whether you regard it from the point of view of digestion, whether you regard it from the point of view of nutrition, or whether you regard it from the point of view of positive harm, I must come to the conclusion that the Plaintiffs have established the truth of the statement that no deleterious action on the flour is caused by the above-mentioned treatment." (*Reports of Patent Cases*, XXVI, 1909, 597.)

Bleaching is permitted in England.

462. Bleaching and Flavour and Texture.—Although bleaching may materially improve the colour of a flour, it does not thereby change a lower grade flour into a higher grade one. There may be some conditioning, but the essentials of the lower grade flour still remain unchanged. Flour of the highest grade possesses a delicacy of flavour, and in the resultant bread or biscuits, a silkiness of texture, which are not present in inferior grades. Even if bleaching causes the lower grade to simulate the highest in colour, it is not simultaneously converted into flour of the flavour and texture of the highest grade.

This line of argument must not, however, be pushed too far. During the whole development of milling processes, there has been a steady increase in the amount of patent flour obtainable from the wheat. At first, only a very small quantity of patent flour of the very best colour was produced. The remainder contained the rest of the flour, darkened by the presence of milling impurities. The patent flour was not only of good colour, but it was also distinguished from the residual flour by the greater delicacy of flavour and fine texture before referred to. With improvements in milling more of this residual flour was freed from its impurities, and obtained of equal colour to the so-called patent flour. The yield of patent flour of the standard colour was thereby increased; but save in colour, the better purification of the former residual flour did not alter the inherent qualities of the flour itself. Yet no one has regarded this transference of such flour to the patent portion as being in any way illegitimate. By parity of reasoning, an increase of the amount of flour of patent colour standard, by harmless bleaching processes, cannot be regarded as an adulteration, nor is such flour misbranded when called "patent flour."

463. Detection of Bleached Flour, Griess-Ilosvay Test.—This was a test for nitrites, devised originally by Griess, and improved by Ilosvay. The test is so delicate that one part of nitrous anhydride, N_2O_3, in a thousand millions parts of water may be detected by its means.

The Griess-Ilosvay Reagent is prepared in the following manner: For solution No. I., 0.5 gram of sulphanilic acid is dissolved by heat in 150 c.c. of dilute (20 per cent.) acetic acid. Solution No. II., 0.1 gram of α-naphthylamine is heated with 20 c.c. of strong acetic acid, the colourless solution is poured off and mixed with 130 c.c. of dilute acetic acid. The two solutions are kept separate, and when required for use are mixed in equal proportions. The mixture is not affected by light, but should be protected from the air. This reagent produces a more or less intense pink colouration in the presence of nitrous acid and nitrites.

Mode of Testing.—The writers found no unbleached flour to respond to this test when made with the necessary safeguards; but they regard the precautions necessary as being extraordinary. The nitrous acid present in the air of laboratories is sufficient to give a pink colouration with unbleached flours. The following method of working is therefore recommended. A laboratory table should be fitted up in the open air. The water to be used must be tested by the Griess-Ilosvay reagent in order to ensure the absence of nitrites. All apparatus, and especially the filter papers placed in funnels, are to be washed with nitrite-free water, and in the case of the latter until the washings give no reaction when tested for nitrites. Twenty grams of the flour to be tested, and 200 c.c. of water, are to be placed in a stoppered bottle and shaken at intervals for half-an-hour. The mixture is allowed to settle, and a portion of the supernatant liquid filtered through a washed filter. Ten c.c. of this filtrate are diluted with 50 c.c. of water, 2 c.c. of the Griess-Ilosvay reagent added, and heated in a water-bath to 80° C. for 15 minutes. In the absence of a pink colouration, there are no nitrites in the flour. In the presence of a pink colour, a comparison is made in Nessler glasses with a solution of a known quantity of nitrite tested in the same way. Tested in this manner, twenty-one samples of flour from mills without bleaching plant gave no reaction for nitrites. Of samples sent as bleached flours fifty-six reacted, while two gave no reaction. These two were probably sent by mistake, as their colour gave no signs of bleaching.

From experiments made the writers satisfied themselves that bleached samples of flour lying side by side with unbleached ones do not impart any nitrous fumes or nitrites to the latter.

The average amount of nitrite, expressed as sodium nitrite, in all the bleached samples was 6.3 parts per million.

In a graduated series of tests, nitric oxide with excess of air was added to flour in measured quantity. There was a gradual increase in whiteness up to the addition of 125 c.c. of gas to a kilogram of flour (37.5 of nitrites per million) after which larger quantities of gas produced a less white flour. With even the maximum bleaching effect, the odour of the flour remained perfectly agreeable.

CHAPTER XVII.

BREAD-MAKING.

464. Salt, Sodium Chloride, NaCl.—Having fully dealt with flour and yeast, there now remain only salt and water as essential constituents of bread; some brief reference must be made to these compounds. Salt is a white crystalline body, about equally soluble in either hot or cold water, and having a characteristic saline taste. Salt is used in the making of bread for two reasons—first, to give the necessary flavour, without which bread would be tasteless and insipid. In addition to its own saline flavour, experiments have shown that the presence of salt stimulates the capacity of the palate for recognising flavours of other substances. Thus, minute quantities of sugar are recognised in the presence of salt which in its absence would be unnoticed. This doubtless is one of the reasons for the importance of salt as a flavouring agent.

In the second place, salt actively controls some of the chemical changes which proceed during fermentation; thus, salt, in the quantities employed in bread-making, produces a decidedly binding effect on the gluten of the dough. It further checks diastasis, and so retards the conversion of the starch of the flour into dextrin and maltose. Salt also checks alcoholic fermentation; the results of careful measurement of this action are given in Chapter XI., paragraph 371. The retarding influence of salt also extends to the other ferments, as lactic, viscous or ropy ferments, and so tends to prevent injurious fermentation going on in the dough.

465. Water.—In considering the quality of water for dietetic purposes, the chemist, first and foremost, addresses himself to the task of determining whether or not the water shows evidences of previous sewage contamination. He next ascertains the hardness and also the amount of saline matters present. The methods he adopts for this purpose vary, but the conclusion at which he seeks to arrive is practically the same. It may be safely laid down as a rule for the baker that a water which would be rejected, on analysis, as unfit for drinking purposes, should also without hesitation be rejected by him. Water containing living organisms should in particular be carefully avoided, as these might very possibly set up putrefactive fermentation during panification.

Among the waters which would be passed by the chemist for drinking purposes, there exist, however, considerable differences. Thus, some are hard, others are extremely soft; salt may be present in certain waters, while in others it may be almost absent. The difference between hard and soft waters is that the former contain carbonates and sulphates of lime or magnesia in solution; the act of boiling precipitates the carbonates as a fur on the vessel used, and so hardness due to the carbonates is termed temporary hardness, in distinction from that of the sulphates which, not being removed by boiling, constitutes permanent hardness.

Much speculation exists as to whether or not the hardness or otherwise of a water exerts any practical influence on bread-making. In brewing it is recognised that a soft water obtains more extract from the malt than a hard one, but the comparison with the case of bread is scarcely fair, because in the wort the liquid is filtered off from the "grains," while in bread the whole mass, whether soluble or insoluble, goes into the oven together. The general tendencies of hard water would be to dissolve less of the proteins than would a soft water, and consequently the dough in the former case would be, to the extent of the action of the hard water, tighter and tougher than that produced when the water is soft. (It will be remembered that gliadin is soluble in distilled water, but that the salts of the flour itself are sufficient to prevent its going into solution.) The use of very soft water is very nearly equivalent to the result produced by using softer flours. Thus, hard water will tend to make whiter bread, because, not only is the quantity of proteins dissolved smaller, but with the same quantity in solution their action would be checked by the presence of the soluble lime salts. At the same time the bread would eat somewhat harsher and drier than that made with soft water. Speaking generally the changes which go on during panification proceed more rapidly with soft than with hard water. Working in a similar manner, *i. e.*, with the same times and temperatures, hard water is not likely to produce as good results as soft water at its best. In order to obtain the same results, the various steps in the process of fermentation should be somewhat modified; thus, the bread would probably require to lie somewhat longer in the sponge and dough stages, or the temperature employed might be somewhat higher. Both colour and flavour of bread depend on fermentation being allowed to proceed to exactly the right point and no further—hence hard water, by altering the length of the fermenting process, will affect both these when fermentation is carried out under precisely the same conditions with hard water as with soft. Further, as the keeping moist of bread depends largely on the degree of change produced in the gluten and other constituents, it is quite possible that the rate of drying may be affected by the use of hard water. Some years ago one of the authors made a series of experiments on the manufacturing scale on the comparative advantages of hard and soft water for bread-making purposes. The use of a water-softening plant was afforded him by the inventors, and over some weeks the character of bread made with the very hard water of the district compared with that made from the softened water. The general conclusion was that no very great difference was caused, or at least no difference that could not be produced by other modifications under the control of the baker, such as slight alterations of the blend of the flour, or mode of fermentation. So far as it went the action of soft water was considered, everything else being equal, an improvement on the hard.

466. Objects of Bread-Making.—The miller's art is directed to the task of separating that part of wheat most suitable for human food from the bran and other substances whose presence is deemed undesirable. The flour thus produced requires to be submitted to some cooking operation before it is fitted for ordinary consumption. Given the flour, it is the baker's object to cook it so that the result may be an article pleasing to the sight, agreeable to the taste, nutritious, and easy of digestion. It is universally admitted that these ends are best accomplished by mixing the flour with water, so as to form a dough; which dough is charged, in some way, with gas, so as to distend it, and then baked. The result is a loaf whose interior has a delicate, spongy structure, which causes good bread to be, of all wheat foods, the one most readily and easily digested when eaten. This charging with gas is most commonly effected by fermentation, but other methods are also to a limited extent adopted: these will be described in turn. Fermentation has one great advantage over other bread-making processes, in that it not only produces gas, but effects other important changes in certain of the constituents of flour.

467. Definitions of various Stages of Bread-making.—The methods employed in the manufacture of bread differ in various parts of the country: it will be well to first give a few definitions, and then proceed to describe and discuss the principal methods and their underlying principles.

468. The Ferment.—Among the older bakers the first step in bread-making was the preparation of a "ferment." This most commonly consisted of potatoes, boiled and mashed with water into a moderately thin liquor, to which a little raw flour was generally added. The yeast was next introduced, and fermentation allowed to proceed until the whole of the fermentable matter was exhausted, and a quiescent stage reached. The essential point about a ferment is that it shall contain saccharine matters and yeast stimulants in such a form as to favour growth and reproduction of yeast, and growth and reproduction in a particularly vigorous condition. For this purpose it is necessary that the ferment be not too concentrated, because no yeast reproduction occurs with too great a degree of concentration. On Briant's authority the following table is given in the Quarterly Trade Review (*Bakers' Q.T.R.*) :—

Concentration of the Medium in which Yeast was grown.	Extent of Yeast Reproduction.
6 per cent. of solid matter	6.60 times.
10 " " "	7.37 "
14 " " "	14.20 "
19 " " "	10.10 "
25 " " "	12.50 "
36 " " "	No reproduction.

A medium containing about 14 per cent. of solid matter is here indicated as being most favourable for reproduction. Independently of this, too, the actual quantity of ferment, as compared with quantity of yeast, is of importance; for on referring to Adrian Brown on fermentation (Chapter IX.), it is seen that too great a crowding of yeast cells, independently of the composition of the liquid, may permit fermentation, while absolutely inhibiting reproduction.

The introduction of raw flour possesses some interest in view of the light thrown on the toxic nature of flour toward yeast in paragraph 377. Such raw flour cannot act as a stimulant to the yeast in the ferment, but may possibly serve to inure the yeast to the effects produced thereon by flour.

Various substitutes for potatoes may be used in the ferment; among these are raw and scalded flour, malt, malt extracts, and other preparations.

469. The Sponge.—This consists of a portion only of the flour that it is intended to convert into bread, taken and made into a comparatively slack dough, with a portion or the whole of the water to be used in making all the flour into bread. The yeast or the "ferment" (together with usually a small proportion of salt) is incorporated into the sponge. Sponges containing the whole of the water are termed "batter" or "flying" sponges. Because of its greater slackness, compared with dough, fermentative changes proceed more rapidly in the sponge. One of the authors made a series of observations on small fermenting sponges made in the laboratory with distillers' yeast; these were very slack, and the number of yeast cells was counted by means of the hæmatimeter immediately on mixing, and again subsequently at intervals of about two hours. Not only was there no reproduction, but the cells present gradually lessened in number, doubtless as a result of disintegration of those deficient in life and vigour. From this, and the reproduction table given under the heading of Ferment, the conclusion is drawn that **no reproduction whatever of yeast** (*Saccharomyces cerevisiæ*) **occurs in the sponge.**

470. The Dough.—This consists of the whole of the flour to be used, together with the whole of the water and other constituents of the bread, whether mixed straight off or with intermediate stages of ferment and sponge.

471. Various Methods of Bread-Making.—Among these may be included the following:—

Dough made right off—Off-hand or Straight Doughs.
Ferment and Dough.
Sponge and Dough.
Ferment, Sponge and Dough.
Flour Barm, Sponge, and Dough—Scotch System.

A useful classification of bread-making processes on this principle is given in an article on "The Best System of Bread-Making," contributed to the National Association Review (late Q.T.R.), by W. T. Callard. The following arrangement has been suggested by Callard's paper:—

472. Off-hand Doughs.—In this system the dough is made direct, without any preceding stages of ferment or sponge.

Types of Bread made by Method.—Sometimes employed in making tin bread (*i. e.*, bread baked in tins) but also at times for making crusty bread.

Flours Used.—Strong patent flours, mixed very slack for tin bread. Strong London households for crusty cottage bread.

Dough-Making.—Generally from 1¼ lbs. to 2 lbs. of distillers' yeast taken to the sack (280 lbs.), with sometimes a little brewers' yeast in addition. Formerly from 10 to 14 lbs. of boiled potatoes were also added, but this appears to be no longer the rule. Salt from 3 to 3½ lbs. per sack. The slack tin-bread doughs, containing 70 quarts water per sack, are frequently made by hand, and fermented at a temperature of about 76-80° F. when mixed: they lie for about ten hours, and yield about 104 loaves per sack.

For cottage bread the dough is made much stiffer, about 60 quarts of water per sack, and usually allowed to ferment at a higher temperature, so as to be ready in about six hours. These tight doughs are generally made by machinery, or else the dough is made at first somewhat slack, and then "cut back" and dusted up at intervals.

Economic Advantages and Disadvantages.—All labour of sponging and extra manipulation saved, bread produced in less time, only one blend of flour and one doughing operation. An increased cost results from the large quantity of yeast required; also number of troughs and consequent space necessary is considerable.

Character of Bread—Appearance.—Very red and fiery in crust, not clear in the partings of the crust, volume fair. When used for cottage bread, a small and rough-looking loaf is the result.

Yield.—Large, the high proportion of yeast enabling the flour to carry considerable quantities of water.

Flavour.—Sweet, but somewhat neutral at times, and even harsh, when fermentation has been pressed to the utmost extent. In cottage bread, when forced, to get a big loaf, there is often a tendency to sourness.

Texture.—Poor, loaf devoid of silkiness or pile, holes of aeration unequal, and cottages small and close.

Colour.—Dull, and devoid of sheen.

Moisture.—High, even to clamminess in some loaves.

Summary.—A system in which colour and appearance are sacrificed to moisture and convenience of working.

473. Ferment and Dough.—As the term implies, this bread-making system is one in which a ferment and dough are employed.

Types of Bread made by Method.—Used very largely in London and the South of England in the manufacture of crusty bread, and also well adapted for tin bread.

Flours Used.—These should be fairly soft, and spring Americans should not exceed 40 per cent. of the whole mixture. Of hard wheat flours, Russians seem to suit this method of bread-making better than the spring American, owing to their glutens mellowing down more rapidly. Some bakers who work by this method claim to use English wheat flours to the exclusion of all other varieties. Winter American patents and also Hungarian flours answer well in this type of bread.

The Ferment.—This most frequently consists of from 10 to 14 lbs. of potatoes to the sack, boiled or steamed, and then mashed with water so as to yield about 3 gallons of liquor. Brewers' yeast is frequently used in ferments, although recently distillers' yeasts have been similarly worked. The ferment is "ready" in about six hours. Various substances are employed as substitutes for potatoes in ferments.

Dough-Making.—The ferment is taken, together with about 2½ to 3 lbs. salt to the sack, water over all to the extent of about 56 quarts to the sack, and allowed to work fairly warm, say 80-84° F. The dough is allowed to lie for various times, from two to about five hours. This will depend on the working temperature, character of flour, and strength or quantity of ferment used.

Economic Advantages and Disadvantages.—After the labour of preparing the ferment, all that of making and breaking down the sponge is avoided; there is but one blend of flour required; and altogether the cost of manipulation is very little more than that of off-hand doughs subsequent to the ferment. It has the advantage that comparatively few troughs are necessary, because in most cases each can be used several times over during the day's work. The yeast required is not high in amount, but the potatoes used sensibly increase the cost of production, and from their dirty character are a nuisance in the bakery.

Character of Bread—Appearance.—Loaf is usually well risen, bearing in mind the class of flours employed. The crust is rough, inclined to break, and usually "short" and crisp in texture. Is bright and clear, except when too strong dark flours are used.

Yield.—Small, because soft flours are generally employed, say about 90 loaves to the sack.

Flavour.—Good, and particularly suited to the London palate, there being considerable sweetness. As in all cases where ferments are used, there is danger of "yeastiness," unless care is taken that the ferment is not allowed to stand sufficiently long for lactic or other foreign fermentation to proceed unduly at the close of the alcoholic fermentation.

Texture.—Close and even (*i.e.*, holes of aeration regular), but not silky.

Colour.—Good, with nice bloom; crust tendency to brownness, but should be free from any foxy tint, the result of absence of very hard flours. Crumbs clear and bright, but comparatively devoid of sheen.

Moisture.—Fair, when bread is first made; but all bread of this kind has seen its best twelve hours after leaving the oven.

Summary.—A very useful system of bread-making, well adapted to districts where bread is eaten very fresh.

474. Sponge and Dough.—This is probably the most widely used of all bread-making methods, and evidently therefore adapts itself well to diversified requirements.

Types of Bread made by Method.—Almost every kind of bread, from the tightest crusty bread dough to that for the slackest tin bread, may be made in this manner.

Flours Used.—Practically every variety of bread-flour offered to the baker can be utilised in this method; the great advantage is that hard flours can be used in the sponge, thus giving them the advantage of long fermentation, while softer flours are appropriately worked in at the dough stage.

Sponge-Making or "Setting."—A blend of hard flour is used for this purpose, and a quantity taken equal to from a quarter to a half the whole of the flour to be used. A frequent plan is to take a bag (140 lbs.) of spring American patents for the sponge, and a sack of home-milled softer flour for the dough. Sufficient water must be taken to make the sponge-dough very slack, say from 6½ to 8 gallons of water to the 100 lbs. of flour. Distillers' yeast is now most frequently employed, and a quantity may be taken of from 6 to 10 ounces to the sack of flour (over sponge and dough); if wished brewers' yeast may be employed instead, but the quantity must considerably vary according to the strength of the yeast. A little salt is usually added to the sponge, say about ½ lb. to the sack. Formerly potatoes were occasionally added direct to the sponge: this custom seems now, however, almost obsolete. On being set, the sponge is allowed to ferment for from six to ten hours, according to the temperature, quantity of yeast, character of flour, and other considerations. In machine-bakeries sponges are usually set somewhat stiffer than where sponges and doughs are made by hand.

The Dough.—The sponge, when ready, is taken, mixed with the remainder of the flour, the water, and the salt. Soft, flavoury flours are introduced at this stage, and the dough allowed to lie about two hours. The temperature both of sponges and doughs is governed by how soon either may be wanted, the atmospheric temperature, and other considerations.

Economic Advantages and Disadvantages.—The adaptability of this method is one of its great advantages, and also the readiness with which it lends itself to the selection and use of any variety of flour. There is somewhat greater expense in working, because of the double handling involved in working the sponge as well as the dough. It is doubtful, however, whether this is appreciable in the hand-made bread bakery, as it amounts simply to making the dough in two instalments in the same trough—there is, in fact, an advantage, as the sponge flour will have had time to soften, and get to work more kindly before the full quantity is worked in in the dough.

Character of Bread—Appearance.—Almost any shape of loaf is well made in this manner, the bread is bold, and, generally speaking, of good appearance.

Yield.—With the great elasticity of the system, as a whole, the yield varies considerably according to the character of flours used. Taking a general average, 93 to 96 loaves per sack is a good proportion. If an excess of hard, strong flour is used in order to get more bread than this, the flavour is likely to suffer.

Flavour.—One of the essential characters of this type of bread is that, if well made, it embodies to perfection the natural flavour of the flours, without any adventitious characters introduced with foreign flavouring ingredients. If the flours are well selected, both for sponge and dough, there should be, on the one hand, an absence of that "rawness" characteristic of under fermentation, and of any harshness resulting from destruction of all moisture and sweetness-conferring constituents by over fermentation.

Texture.—The bread should have a good pile, crumb even, white and silky, with full sheen on the fibre of the bread.

Colour.—The crust should be golden brown, without foxiness or abnormal paleness. In the crumb the colour advantage of the class of flour used should be fully developed.

Moisture.—Bread made in this manner is free from any clamminess, and may easily pass over the line into harsh dryness—this, however, is a fault that should not occur, rather than a necessity of the method. From the very even sponginess of the bread, although when fresh cut it may be very moist, yet it tends to rapidly dry out when cut slices are allowed to lie about. But when properly made, this bread retains its moisture in the uncut loaf remarkably well.

Summary.—An interesting point about the sponge and dough method is its comparison with that of ferment and dough; both have their advantages, but that just described for most purposes has the preference. Comparing breads made by the two methods, ferment and dough made bread is at its best when quite fresh; while suitably made sponge and dough bread retains its eating properties considerably longer.

475. Ferment, Sponge, and Dough.—This is essentially a combination of the two immediately preceding methods, and is frequently chosen where brewers' yeast is used, as the ferment exerts a specific and valuable action on yeast of that description. A ferment being employed, instead of adding yeast to the sponge direct, a description of the sponge and dough method applies also to this process. One of its advantages is that it permits more individuality in character of the bread than where a compressed yeast is used, which can be freely purchased by any baker. When by means of a "ferment" the baker practically makes his own yeast, he becomes liable to the risks as well as the advantages accruing from being his own yeast manufacturer. This method is frequently associated with the manufacture of patent yeast by the baker himself. The whole of the various methods previously described are susceptible of the same modifications, except perhaps tight, off-hand, crusty bread doughs which would rise with difficulty under the action of this usually comparatively weak yeast.

476. Present Review of Bread-making Methods, Callard.—Mr. Callard has kindly furnished the authors with the following note on his paper herein quoted:—

"Since writing the paper referred to, considerable changes have taken place in the general practice of bread-making. In the main these changes are due to two causes: (1) the great improvement in the preparation of compressed yeasts, and (2) the advance of English milling.

(1) Compressed yeasts today are of a much higher quality and lower price than when that paper was written. They are much less susceptible to atmospheric changes, and consequently are less damaged in transit. They are stronger, or, to be more correct, they mature quicker in the dough than did yeasts of years ago. This has enabled bakers to dispense with ferments or sponges, and the system of straight doughs has become

almost universal. Where the sponge and dough system survives today, it is on account of attachment to old methods and not because of the necessity of so treating the yeast.

(2) The English miller has for many years aimed at producing a flour of an all-round quality, avoiding harshness on the one extreme and softness on the other. He has tried to produce a flour capable of being used alone. In this he has succeeded, with the result that the flours of today are more mellow than in the past and require less softening during the process of fermentation.

The straight dough system (off-hand) with 1¼ lbs. to 1½ lbs. of yeast, taking about 5 hours to the oven, is general. This occupies the same relative place at present as the sponge and dough did when the paper was published. Here and there a modified ferment is used in conjunction with it to give the yeast a start. When the desire is to shorten the time the yeast is increased, in fact with automatic plants 6 lbs. of yeast is used to the sack, and the dough passes from the mixer to the divider without delay.'' (*Personal Communication,* October, 1910.)

477. Flour Barm, Sponge, and Dough—Scotch System.—The flour barm is practically a combination of the making a baker's malt and hop yeast with a slow, scalded flour ferment. The preparation of the flour barm has been fully described in the earlier part of this work, page 236.

Type of Bread made by Method.—This is the well-known close-packed ''Scotch brick,'' being a high and comparatively narrow loaf, prepared from tough, hard flour of the highest class.

Flours Used.—In sponges, strong patents or straight grades from Duluth or Russian wheats. In doughs, winter Americans and softer, but still tough, home-milled flours.

Sponges.—These are known as ''half'' or ''quarter'' sponges, and consist of either the half or quarter of the whole liquor employed to the sack of flour. The requisite quantity of flour barm is taken, for which, however, distillers' yeast may be substituted without materially altering the character of the bread. About 6 lbs. of salt are used to the sack, one-sixth of which goes into the sponge.

Doughs.—These are made in the usual way, but it is customary to give the dough a very thorough working after it has laid some time. One of the most suitable ways of doing this is by passing the dough repeatedly through a dough-brake.

Economic Advantages and Disadvantages.—The cost of production is, according to the views of the Scotch baker, very low, as he views the yeast as costing him very little, the flour used coming back into the bread. This is not quite correct, because a certain portion must have been changed into alcohol and carbon dioxide during fermentation; and, again, the labour of preparation must cost something.

Character of Bread—Appearance.—The appearance is attractive, the loaves are high, and the sides, where they have been separated from each other, have a very smooth, silky appearance.

Yield.—Large, the character of the flours used permitting this, and also the fact of most of the bread being close packed. An average yield in a large factory has for some months been as much as 101 quarterns per sack.

Flavour.—Characteristic, and marked by the presence of a decided acidity of pure and pleasant taste, due largely, if not entirely, to the presence of lactic acid. The large quantity of salt used gives a saline character to the taste, immediately recognised by the English palate, which also usually misses the sweetness generally found in the best qualities of bread made in the south.

Texture.—Scotch bread has the perfection of texture, being silky with large bulk and pile, and small regular holes of aeration.

Colour.—The long system of baking employed gives the crust a dark brown colour, and hence the bloom of crust is not such an important characteristic as in south country crusty bread. The crumb is exceedingly white, but has comparatively rarely the creamy, yellow bloom seen in some of the bread made in other localities. The sheen of the bread is remarkably distinct, the holes having a rich, full glaze.

Moisture.—Good, and the bread keeps remarkably well.

478. Scotch Bread-making Processes, Meikle.—Mr. J. Meikle, of Glasgow, has favoured the authors with the following specially obtained information. The various data have been submitted to several experienced Scottish bakers, and therefore may be regarded as perfectly trustworthy.

Scottish systems of breadmaking differ a good deal from the processes that obtain in England. Sponging is almost as popular today as it was two decades ago; all serious operations indeed being carried through under some kind of sponging system. The two leading processes, however, are the "quarter" and the "half" sponge.

QUARTER SPONGE, FOR 1½ SACKS OF BREAD.

28 lbs. Water.
70 lbs. Flour.
10 lbs. Barm.
10 oz. Salt.
80° F. Temperature. Time—13 hours.

Sponge.

160 lbs. Water.
126 lbs. Flour.
2½ lbs. Salt.
78° F. Temperature. Time—1¼ hours.

Dough.

20 lbs. Water.
224 lbs. Flour.
5½ lbs. Salt.
78° F. Temperature.

Scale in 1½ hours: the temperatures given are those of sponge, etc., when made.

The quarter system is a three process system. The quarter is made up at night generally and lies about 13 hours; it should then be up and dropped an inch, and is turned into a "sponge" tub—a tub of a capacity of 48 gallons—then water is added, the quarter is well broken, then salt and flour are put in to make a thin sponge. The sponge lies about 75 minutes and is doughed as soon as it shows signs of settling down: this is of course for square batched bread, and nothing can touch this system for appearance: nearly all the bread of Glasgow and the West is made in this way.

HALF SPONGE, 1½ SACKS.

100 lbs. Water.
185 lbs. Flour.
20 lbs. Barm.
1½ lbs. Salt.
80° Temperature. Ready 13 hours time.

Dough.

105 lbs. Water.
235 lbs. Flour.
6½ lbs. Salt.
78° F. Temperature.

Scale in 1¾ hours. Both this and the previous system dough want at least one turn or cut back while lying in dough. This system does not make such picture bread as the quarter, but it eats better, particularly so when distiller's yeast is used. This is the kind of system worked in the North of Ireland; but the length of time the sponge lies is being considerably curtailed in these days.

SHORT SYSTEM.

Short systems of fermentation are making some little headway in Scotland, but probably as a novelty; the following turns out a passable loaf when suitable flours are used.

Short Process Sponge.

70 lbs Water.
74 lbs. Flour.
86° F. Temperature.
½ lb. Salt.
3 lbs. Yeast.
Time—1 hour.

Dough.

145 lbs. Water.
346 lbs. Flour.
7 lbs. Salt.
82° F. Temperature.

Lie 3 hours before scaling. This process does not give the "pile" of sponge bread, but it makes a much better square loaf than a short straight dough system does.

FLOUR USED IN SCOTLAND.

The flour trade in Scotland has undergone great changes during the last fifteen years, for whereas at that time American flour was the only flour that mattered, the imports from the United States are now almost a negligible quantity. But Scotch bakers need strong flours, or what is the same thing practically, they think they need them, and the home millers supply them. Minnesota spring wheat of good quality is of course as scarce as Minnesota flour, and millers use strong Russians and Manitoban wheats instead. Flours from those wheats are used for sponging. For doughing a proportion of American Winters was at one time a favourite, and even now American Winters, or home-milled flours from Australian and Argentine wheats, blended to work like Winters, are much used, with say a proportion of Kansas flour, and some flours of the "Millennium" and "As You Like It" type of English milled flours. There is a wider range of doughing flours, for the kind of flour wanted for this purpose depends upon what has been used in the sponge. The wheats of Manitoba, Kansas, Australia, Argentina, and so on, all come in useful.

For barm flour fine Russian and Manitoban wheats are favourites. This flour is very often a straight run flour; straights suit barm-making best. By the way, about the best virgin barm the writer ever saw made for a length of time was made from Scotch kiln-dried wheat milled on stones. Hungarian flour, once a prime favourite for good class bread, is now almost unknown in Scotland. (*Personal Communication,* October, 1910.)

479. American and Canadian Methods.—The following are representative processes, but the authors had hoped to have opportunities of more closely studying these on the spot.

No. I:—

Flours Used.—Hard flours from Northwest wheats; soft flours from winter wheats. Used in proportions of from two to four parts hard to one of soft.

Yeast.—Almost entirely distillers' compressed yeasts, though baker's malt and hop yeasts are used also.

Improvers.—Malt extract, sugars, fat and milk are used, and to a much greater extent than in British methods.

Modes and Time of Fermentation.—Straight doughs taking from 6 to 8 hours to the table; 12 to 14 hour sponges are also used. The following are quantities for two types of bread—

Real Home Made.—Flour, 784 lbs.; water, 420 lbs.; salt, 14 lbs.; cottolene, 17½ lbs.; yeast, 6 lbs.; malt extract, 5½ lbs. Temperatures: Flour, 70°; bakehouse, 80°; water, 84°; dough, 82° F.

G. Crust.—Flour, 972 lbs.; water, 520 lbs.; salt, 18 lbs.; cottolene, 13½ lbs.; yeast, 7¼ lbs.; condensed milk, 13 lbs.; malt extract, 5 lbs. Temperatures: Flour, 70°; bakehouse, 80°; water, 86°; dough, 83° F.

Machinery is extensively used. Mixers, dividers, moulding machines and rounding-up machines are used in the larger shops, and automatic provers are being introduced. The quantity of hand-made bread is small and decreasing.

Kind of Loaf.—Tin bread almost entirely. Output of hearth baked bread is less than three per cent. of the total, and would probably represent the average.

No. II:—

Flour.—Three parts Minnesota patent to one part Kansas hard wheat.

Yeast.—Compressed yeast.

Improvers.—Malt extract, sugar, lard, milk, cornflour.

Quantities.—850 lbs. flour, 525 lbs. water, 6½ lbs. yeast, 12¾ lbs. salt, 20 lbs., sugar, 17 lbs. lard, 5 lbs. milk powder, 5 lbs. malt extract and 25 lbs. cornflour.

A short time ferment is made with the yeast, malt extract, part of the water, and the cornflour. This is added to the dough after the flour is in. The temperature of the dough is 84° F., and the time from mixer to bench is 5½ hours.

Review of Panary Fermentation.

480. It is proposed in the succeeding paragraphs to consider the nature of the chemical changes which occur during bread or panary (from *panis,* bread) fermentation. Suggestions will also be made as to possible improvements in methods of carrying out the various processes, with the hope that they may lead to the avoidance of those causes which result in the production of bad or inferior bread.

481. The Ferment.—Potatoes, termed by the baker "fruit," constitute the principal ingredient of the ferment; their composition is indicated in the following analyses. No. 1 was grown with mineral manure, No. 2 with a rich nitrogenous manure:—

	No. 1.	No. 2.
Water	76.40	75.20
Starch	14.91	15 58
Proteins	2.17	3.60
Dextrin	2.34	1.29
Sugar	0.15	1.11
Fat	0.29	0.31
Extractive Matter	1.70	1.99
Cellulose	0.99	1.03
Ash	1.00	0.90

Roughly speaking, a potato contains three-quarters of its weight of water and about 15 per cent. of starch; the remainder being made up of small percentages of proteins, dextrin, sugar, and other substances. On being boiled, the starch is gelatinised, and on mashing the potatoes, together with the liquor in which they have been boiled, a starch paste is formed, containing also considerable quantities of dextrin and sugar, and what is of great importance, soluble nitrogenous compounds. Yeast on being sown in this medium sets up an active fermentation, largely due to the sugar already present, together with the strong nitrogenous stimulant. In Chapter XI. it has been demonstrated that the fermentation is almost as active in the filtered potato water as in the mash. It must also not be forgotten that yeast alone is incapable of inducing diastasis in starch paste. Consequently any unaltered starch suffers little change in a ferment containing only boiled potatoes and yeast. But raw flour being also commonly added, the yeast induces a change in the flour proteins, in virtue of which they become somewhat active hydrolysing agents, and so the potato starch is indirectly converted in part into sugar. The yeast, when sown in a ferment, multiplies by growth, and thus a relatively smaller quantity of yeast is enabled to do the after work. A large proportion of the starch of the potato still remains unchanged at the close of the fermentation of the ferment; so also, the nitrogenous matter of the potato in great part remains. When the ferment is added to the sponge, the smaller quantity of yeast not only does more work because of its having had the opportunity of growth and reproduction in the ferment, but also because the nitrogenous matter of the potato still acts as a yeast stimulant in the sponge. The active effect of potato water alone shows that this stimulating action of the ferment on yeast must not be entirely ascribed to the starch present. From the active stimulating nature of the nitrogenous matter of potatoes on yeast, it seems probable that that matter consists of nitrogen in some other form than albuminous compounds. Summing up these changes into one sentence, **in the ferment the yeast acts on the soluble proteins of the flour and enables them to effect, to a limited extent, diastasis of the starch; this results in the production of a saccharine medium in which the yeast grows and reproduces; further, the soluble nitrogenous matter of the potato acts as an energetic yeast stimulant.**

It is essential that the potatoes used in the ferment be sound: they should first of all be washed absolutely clean. A common practice is to place them in a pail or tub, with water, and scrub them with an ordinary bass broom; this treatment is inefficient, as potatoes served in this way still retain a considerable amount of dirt. The potatoes are then boiled in their jackets, and afterwards rubbed through a sieve in order to separate the skins. By far the best plan to clean potatoes is by means of a machine, of which the following type answers well for all practical purposes. The machine consists essentially of an outer tub, in which is fixed a vertical revolving brush: the potatoes are put in, and about two minutes turning the brush cleans them most effectually. The dirt is removed and also a good deal of the outer skin, while the interior of the potato remains intact. Treated in this manner the potatoes have only just the slightest film of skin to be removed, after boiling, by means of the sieve. In the next place, the pan, or other vessel used for boiling the potatoes, should be kept clean; this is only done by its being washed, drained, and wiped dry every day. Not only the potatoes, but the water in which they are boiled, should be quite clean enough, if need be, to go into the bread. At present, many bakers steam their potatoes in preference to boiling: this modification is cleanly and convenient. The potatoes are placed in a metal work cage, which in its turn is placed in a box arrangement, through which steam is conducted from a boiler: when sufficiently cooked, the cage, together with the potatoes, is lifted out, and its contents poured on to a sieve. The ferment should be rapidly cooled to the pitching temperature of about 80° F. in summer, and 85° in winter: in summer it is very important that the baker should throughout conduct his fermentation at as low a temperature as possible. During the time that a ferment is working the temperature should be kept even: for this purpose select a place in the bake-house free from draughts or excessive heats.

At present, flour, together with malt extract and a number of other materials, are being used as substitutes for potatoes in ferments, the use of which is now the exception rather than the rule.

482. Panary Fermentation.—The consideration of the division of this process into sponging and doughing may be postponed until after a study of the nature of the changes occurring during panification as a whole. Yeast, flour, and water, at a suitable temperature, on being mixed so as to form a dough, immediately begin to react on each other. The flour, it must be remembered, contains sugar, starch, and both soluble and insoluble proteins. The yeast consists essentially of *saccharomyces*; but bacterial life is also present in greater or less quantity, not only in the yeast but also in the flour. The yeast rapidly sets up alcoholic fermentation, thus causing the decomposition of the sugar into alcohol and carbon dioxide gas; the latter is retained within the dough and causes its distension. Functioning in dough, no reproduction of the yeast occurs; after a time the yeast cells disappear through the degradation and rupture of their walls. In addition, the yeast attacks the proteins present, effecting changes in them which are similar to, if not identical with, the earlier processes of digestion. Albumin and its congeners are, in fact, more or less peptonised. The gluten, from being hard and india-rubber like, become softer, and within certain limits more elastic; but if fermentation be allowed to proceed too far, the gluten softens still further, and its peculiar elasticity in great part disappears. It is uncertain to what extent these changes in the gluten are due to the specific action of yeast, as they also occur, although more slowly, in flour which has simply been mixed with water. It has been already explained that under the action of yeast the albuminous bodies of flour acquire the power of effecting the diastasis of starch; this compound is consequently to some extent converted into dextrin and maltose during panification. The amount of starch so hydrolysed depends largely on the soundness of the flour. In addition, the diastase of the flour itself will probably have some action in inducing starch conversion. The lower the grade of the flour, the more raw grain diastase it usually contains. When potatoes are used, whether as a ferment or as a direct addition to the flour, they furnish soluble starch, and also act as a nitrogenous yeast stimulant. While the yeast effects important changes in the albuminous compounds of flour, experiments made and described in Chapter XI. show that little or no gas is evolved as a consequence of such changes. The gas produced in dough during bread-making is the result of normal alcoholic fermentation of sugar by the yeast. **Summing up the changes produced in panification—they are alcoholic fermentation of the sugar, softening and proteolytic action on the proteins, and a limited diastasis of the starch by the proteins so changed.**

So much for the action of yeast on dough. The next point of importance is the effect produced by such other organisms as may be present. The principal one of these is the lactic *bacillus;* under its influence the sugar of the dough is converted into lactic acid. Either the organism itself, or the acid produced by its action on sugar, has a softening and dissolving effect upon gluten. Opinions differ as to the desirability, or otherwise, of the presence of lactic ferments in yeast used for bread-making. It has already been explained that their being found in any but the smallest quantity in brewers' or compressed yeasts is an unfavourable sign, as they show that due care has not been taken in the manufacture of the yeast; for that reason their presence is deemed unfavourable. In Scotch flour barms the presence of lactic ferments in not too great amount is deliberately encouraged; experience having shown that if the barms be brewed so as to exclude these organisms such good bread is not produced. In Scotch bread-making very hard and stable flours are used; the lactic ferment does good service in softening the gluten. It is possible also that during the long period of sponging and doughing, the changes induced by the lactic ferment may cause slight evolution of gas; but so far as actual aeration of the dough is concerned this may be viewed as a negligible quantity. It must be remembered that the *soupçon* of slight buttermilk flavour is a valued characteristic of Scotch bread. In bread-making, as conducted by most English processes, particularly with soft flours having but little stability, there seems no useful function which the lactic ferment can perform; its absence is therefore rather to be desired than its presence. A yeast may contain other organisms in addition to those just mentioned; these are capable of inducing changes of a far more serious nature than does the lactic ferment. Among these there are the organisms which cause butyric and putrefactive fermentation. That bane of the baker, sour bread, is commonly ascribed to the action of either lactic or acetic fermentation; it is, however, far more probable that this unwelcome change is due to incipient putrefactive and butyric fermentation; since the odour of a sour loaf is very different from that of either the vinegar-like smell of acetic acid or the buttermilk odour accompanying lactic acid in altered milk. The souring takes place more usually in the bread rather than in the dough.

In order to produce a healthy fermentation in dough, healthy yeast is of vital importance: purity from foreign organisms is desirable (saving, perhaps, a small proportion of lactic ferment in flour barms), but above all the yeast itself must be active and in good condition. Given a yeast, which contains a certain percentage of foreign ferments, those ferments will be held in abeyance while the yeast itself is energetic and healthy. Bakers are often puzzled by microscopic observations of yeast; they find that, of two yeasts, one produces sour and the other a good bread, and yet that the two contain about the same quantities of disease ferments. They are consequently very apt to despise any conclusions they may have drawn from microscopic observations; but the difference in such cases lies in the yeast itself: the one will be healthy, the other weak and languid. Quoting again from previously described experiments, in the same sample of wort, divided into two portions, the one only of which was sown with yeast, and both equally exposed to the air, it was found that in the presence of yeast life, *bacteria* refused to develop, while in its absence they reproduced with enormous rapidity. In the same way the healthy yeast suspends the developments of *bacteria* in dough, while the yeast being weak and almost inactive, bacterial life flourishes apace. Examination would reveal that in most cases of unhealthy panary fermentation the fault is as much due to the yeast itself as to the abnormal presence of foreign ferments.

483. Sponging and Doughing.—This division of the process of panary fermentation into two distinct steps is of extreme interest. The origin, and reasons which led to the adoption, of this mode of procedure are probably due to the exigencies of dough-kneading by hand. For even when using flour from the lot which has been placed in his trough, the baker usually elects to work a part of it into a sponge first. The reason, or at least one reason, is that the dough softens on standing, and therefore there is less work involved in mixing in the flour in two instalments than in one, as the first lot will have got considerably softer. Further, very little experimental work in this direction will have shown the baker that he required to use less yeast, and got better results when working in this way. Hence, doubtless, for original reasons such as these, the division of bread-making into sponge and dough. Independently of this, they have for other reasons a most important scientific justification. The reader will by this time be familiar with the division of flours into strong and weak varieties. The various tests given in a preceding chapter show not merely that one flour absorbs more water than another to form a dough of standard stiffness, but also that some flours fall off far more rapidly in stiffness than do others when kept in the condition of dough. There are therefore two distinct properties here to be considered in relation to flour, the absolute quantity of water it absorbs, and also the rate at which slackening goes on during panification. Remembering the previous definition of water-absorbing power, **the relative capacity of resistance of flours, to a falling off in water-retaining power during fermentation, may appropriately be termed their "Stability."** As a rule, the strong flours are also the more stable, but this does not necessarily hold good in all cases. It has been already explained that, for the production of the best bread, fermentation should be allowed to proceed sufficiently far to soften and mellow the gluten, but no further. At stages either earlier or later than this, the bread will lack both in appearance and flavour. It is therefore necessary to so regulate fermentation as to stop at precisely this point; unfortunately no exact means are at present known whereby it can be determined with precision. The more stable a flour is, the longer it requires to be fermented before this point is reached, hence where flours of different qualities are being used, the more stable should be set fermenting earlier than the others. In this lies the reason for using some flours at the sponge and others at the dough stage. Flours from hard wheats, such as Spring American or Russian, should be used in the sponge; and American Winter or English wheaten flours in the dough. Working with stable flours in the sponge, experience has shown according at least to the London practice, that the best results are obtained by allowing the sponge to rise and fall once, and then to rise again. The time taken for this rising and falling is found to agree with that necessary for the sufficient mellowing of the gluten. This empirical test, which is the result of careful watching and experience, is at present the baker's principal guide in determining the progress of fermentation. It affords evidence of the degree of rapidity with which gas is being evolved, and indirectly of the extent to which the other chemical changes have proceeded.

Reference has already been made to the great change which has during the past few years come on baker's practice. For various reasons, among which those cited by Callard are some of the leading ones, the sponge and dough methods have largely given place to straight or off-hand doughs. Possibly the exigencies of hand kneading, referred to at the commencement of this paragraph, have so completely disappeared, with the greater adoption of machinery, by which a stiff straight dough is readily made, that any division of the dough-making process is no longer found or deemed necessary.

484. Variety and Quantity of Yeast Used.—The variety of yeast employed produces a marked effect on the character of the resultant bread. Good brewers' yeast is almost universally admitted to induce a characteristic sweet or "nutty" flavour, hence it has been largely used in the manufacture of so-called farmhouse bread. Colour in this variety of bread is secondary to sweetness of flavour. While brewers' yeast has a somewhat energetic diastatic action on the proteins and starch of dough, its fermentative power is comparatively low in that medium. Undoubtedly, one of the reasons which has led to the comparatively extensive use of potatoes in bread-making is their stimulant action on the gas-producing power of brewers' yeast in dough.

Compressed distillers' yeasts, on the other hand, are marked by their rapid power of inducing alcoholic fermentation in dough: experience indicates that neither potato nor flour ferments are necessary, at least as stimulants, when working with these yeasts.

Motives of economy on the part of the bakers, and competition on the side of the yeast merchants, both lead to a certain rivalry among the latter as to whose yeast is able, weight for weight, to adequately ferment the greatest quantity of flour. Now, while it is important that the baker should know with accuracy the relative strengths of different brands of yeast, it is nevertheless not wise to be too sparing in the quantity employed to a sack of flour. First, select the strongest and purest yeast you can get for the money, and then don't be afraid to use sufficient of it. This advice should have especial weight where soft, weak flours, having comparatively little stability, are so largely employed. Flours of this kind will not bear being kept so long in the sponge and dough stage as is necessary to ferment them with a very small quantity of yeast; they, if so treated, produce sodden, heavy, and sometimes sour loaves; when any saving in yeast is more than compensated by a less yield of bread.

485. Management of Sponging and Doughing.—In order to insure success in the manufacture of bread, sound materials are the first requisite; after that the most important in this, like all other operations in which fermentation employs an important part, is the proper regulation of temperature. The yeast should always be stored where it will get neither too hot nor too cold; for extremes of temperature in either direction weaken the action of yeast. Brewers' yeast in particular suffers from this in summer weather; and so, many bakers who use it in the winter change over to compressed yeast in the summer. In summer time the compressed yeasts, are when fresh more active than in winter: in the latter season, the strength of the yeast may be increased by allowing it to stand for a time in water at 85° F. before being used. A still better plan is to stir a small quantity of sugar or malt extract into a bowl of water and then add the yeast; let this stand for about an hour, gently stirring now and then in order to aerate the liquor. Such treatment refreshes and invigorates the yeast, and so enables it to afterwards work more actively. Both sponge and dough, or straight dough, should be so managed as to keep the temperature as nearly constant as possible during the whole of the fermentation. Good yeast works well at from 80° to 85° F., and at that temperature lactic and butyric fermentation proceed but slowly, even in the presence of the special organisms which induce these types of fermentation. Sudden cold should also be avoided, as a chill to working yeast is most detrimental, causing fermentation to entirely cease, or at the best to proceed most sluggishly. Such a sudden lowering of temperature may indirectly be the means of producing a sour loaf.

486. Use of Salt.—A great deal has been written as to the use of salt as a guiding agent in fermentation; so far as the yeast is concerned, salt is generally viewed as having a retarding influence; although the opinion has been expressed that quantities of salt under 3 per cent. of the water used stimulate the action of yeast. This opinion is based on certain observations of Liebig. The authors' own experiments (*vide* Chapter XI., paragraph 371) lead them to conclude that salt, in all proportions from 1.4 per cent. upwards, retards alcoholic fermentation, and diminishes the speed of gas evolution. Salt acts still more powerfully as a retarding agent on lactic and other foreign ferments, and so aids in the prevention of unhealthy fermentation. In addition, salt also checks diastasis, and thereby prevents undue hydrolysis of the starch of the flour. In summer time, or when any suspicion of instability attaches to the flour, it is well to add some portion of the salt to the sponge; but when the flour is good, and the yeast pure and healthy, the whole of the salt may be deferred to the dough stage.

In the Scotch methods of bread-making, flours of a very strong and stable character are used in the sponge, which altogether is allowed to stand about 12 hours. A slight amount of lactic acidity is developed in this, and is viewed as normal; it has an important function in softening and mellowing the gluten. It will be noticed that a small proportion of salt is, in the Scotch process, added to the sponge.

487. Loss during Fermentation.—This has been variously estimated, among the highest figures being that of Dauglish, who introduced the aeration process, and expressed the opinion that this loss amounted to from 3 to 6 per cent. In order to determine the maximum amount of loss possible, the authors made a direct experiment—100 parts by weight of soft flour from English wheats were made into a dough with distilled water, two parts of pressed yeast being added; no salt being used. This dough was allowed to stand for from 8 to 9 hours at a temperature of about 85° to 90° F.; fermentation proceeded violently, but towards the end of the time had apparently ceased. The dough was then placed in a hot-water oven, and maintained at a constant temperature of 212° F. for 10 days; the same weight of flour and yeast, but no water, was also placed in the oven. At the end of that time the fermented dough was found to have lost 2.5 per cent. compared with the flour. Now in this extreme case a soft flour was used with distilled water and no salt, and about six times the normal amount of yeast; the temperature was purposely maintained at a high point, and the fermentation carried on so long as any decided evolution of gas occurred. Yet, under these conditions, which far and away exceed in severity any such as are met with in practice, the loss was less than Dauglish's minimum estimate. In the fermentation experiments described in Chapter XV., paragraph 436, the total loss in weight of the dough during fermentation was only 0.59 per cent. with a strong flour, and 0.70 per cent. with a weak flour. In both cases the extent of fermentation was as nearly as possible that normally employed in modern bread-making processes.

488. Baking.—For baking, the oven should be at a temperature of 450-500° F. Most modern ovens are now fitted with a pyrometer, by means of which the temperature may be read off. If depending on this instrument, care must be taken that it is in efficient working order. In the oven the dough rapidly swells from the expansion of the gases within the loaf by the heat. Its outside is converted into a crust; the starch being changed into gum and sugar: these are at the high temperature slightly caramelised, and so give the crust its characteristic colour. The effect of the heat on the interior of each loaf is to evaporate a portion of the water present in the dough: the carbon dioxide, and a portion of the alcohol produced by fermentation, escape with the steam, and may be recovered from the gases within the oven. While any water is present in the bread, the temperature of its interior can never rise above the boiling point of that liquid. Owing to the pressure caused by the confining action of the crust, that boiling point may, however, be somewhat higher than under normal atmospheric pressure. The increase due from this cause is probably not more than some two or three degrees. As baked bread still contains some 35 to 40 per cent. of moisture, it may be safely stated that the inside of the loaf never rises to a higher temperature than 215° F. It is commonly stated that, in the act of baking, the starch of flour is gelatinised. This, however, is only partly the case. The temperature of a baked loaf rises considerably above that requisite for gelatinisation, but there is also another condition necessary. Gelatinisation is essentially an act of union with water, and a loaf does not contain sufficient moisture to anything like gelatinise the whole of the starch. At the moment of writing, a fragment of bread has just been examined microscopically, and field after field is seen of unbroken and apparently unaltered starch corpuscles. One of the largest present was measured and found to be 0.057 m.m. in diameter, showing that the starch had not even materially swollen. Doubtless under the influence of heat the starch has become softened, but the larger proportion of the granules still remain intact. (Compare paragraph 172, page 80.) At the temperature of the interior of the loaf, the coagulable proteins will have been coagulated, and their diastatic power entirely destroyed. The composition of bread, compared with that of flour, is dealt with subsequently.

489. Time Necessary for Baking.—The time during which bread is kept in the oven varies considerably in different parts of the country: much must depend on the temperature—whether the oven be quick or slack. For 4 lb. crusty loaves an hour to an hour and a quarter seems to be an average time. The half-quartern or 2 lb. loaf is a much commoner size in England, and loaves of this description can readily be baked in from 40 to 50 minutes in any well constructed oven.

490. Glazing.—The admission of steam to an oven, when properly managed, has the effect of producing a glazed surface on the outside of the crust: this operation is familiar to bakers as that by which Vienna rolls are glazed. In order that the operation shall be effective, the bread or rolls should be as cool as possible. The steam should be simply at atmospheric pressure, and saturated with moisture. At the instant of the cool loaf entering the steam atmosphere of the oven, a momentary condensation of steam occurs over the whole surface, which is thus covered with a film of water at the boiling point. This renders the starch of the outside surface soluble, and as the water dries off leaves a glaze of soluble starch, part of which possibly has been converted into dextrin. The injection of steam into the oven not only helps to dextrinise and glaze the crust, but also serves the purpose of keeping the interior of the loaf moist by preventing too rapid evaporation.

491. "Solid" and "Flash" Heats.—These terms are frequently used by the baker in speaking of the character of the heat of different ovens. The former is applied to heat which is continuous, the latter to heat which is very temporary, but frequently for the moment intense. It will be found that the so-called "solid" heat is usually evolved from the walls of a well heated oven. A good oven should have plenty of material about it; this gets hot through, and afterwards radiates heat slowly but continuously. If the oven walls be too thin they cool too quickly; in consequence they have to be heated very intensely at the start; the result is that the oven at first burns the bread, and towards the end has not heat enough to complete the baking of the batch. With thicker walls the initial temperature of the oven need not be so high; the fall in temperature taking place more slowly, the oven still retains a good heat at the close of the baking. The heat which reaches the bread from the walls of the oven is largely in the form known as "radiant" heat; it is continuous, and need not be of abnormally high temperature in order to thoroughly and efficiently bake bread. The consequence is that the interior of the bread is well baked, while the crust is not burned.

A "flash" heat, on the other hand, is produced by the contact of highly heated gases with the bread. Certain varieties of ovens are fired by the introduction of flame into the oven itself. Such introduction of flame should be employed to previously raise the temperature of the oven, not, if used at all, to bake the bread itself. The reason is obvious; it is exceedingly difficult to regulate the temperature of a current of hot air from a flame with great exactitude. The temperature is sufficiently high at one time to burn the crust; at another so low as to prevent, during the time the bread is in the oven, its inside being sufficiently cooked. Further, if the bread is to be heated by the hot air resulting from the direct admission of flame into the oven, there must necessarily be also some means of exit for the gases from the flame. The hot air from a furnace cannot, in fact, be drawn into the oven without some means for their after escape. The result is that these gases carry with them the steam evolved from the baking loaves, and so subject the bread to a dry, instead of a steam saturated, atmosphere.

492. Cooling of Bread.—The loaves on being taken from the oven should be cooled as rapidly as possible in a pure atmosphere; for this purpose, where practicable, open-air cooling sheds should be provided. Failing these, the cooling-room must be well ventilated. It goes without saying that the cooling loaves must be adequately protected from rain.

493. Summary of Conditions Affecting Speed of Fermentation.—Where fermentation starts with the first addition of yeast to the other materials, it does not conclude till the bread has been for some time in the oven, and possibly not even then. At this stage of work, with both principles and details of methods of working explained, a bird's-eye view of the whole course of fermentation should be of service.

A ferment, when used, is a means of making yeast by a process of reproduction from that originally added. Steps are taken at the same time to ensure vigour in the new yeast formed. The speed of fermentation of the ferment is hastened by increase of temperature, but beyond a certain point that of acid-producing organisms is also more than proportionately stimulated. Aeration during fermentation tends to increase the vigour of the produced yeast. (Compare Adrian Brown on the action of oxygen on fermentation, paragraph 310).

Assuming a start has been made with either sponge or off-hand dough, the same laws govern fermentation.

First, let us see **what conditions accelerate fermentation.**

With regard to yeast, the greater the quantity, the more quickly it proceeds: with *sound* yeast there is no fear of imparting a yeasty taste to bread with many times more than necessary for ordinary bread-making. The strength of the yeast will also directly tend to increase the rate at which fermentation proceeds.

Flour.—Soft flours tend to hasten fermentation; they contain more sugar and more starch in a condition susceptible to diastasis. Their protein matter is more likely to act as a yeast stimulant, while the softness of the gluten lessens a physical obstacle to rapid action of yeast.

Potatoes, Saccharine Extracts.—These act as stimulants, and tend to increase the speed of fermentation.

Water.—The principal way in which this acts is in virtue of the proportionate quantity used. When doughs are slack, fermentation proceeds much more rapidly.

Aeration.—Flour well aerated is likely to work more rapidly, especially in slack sponges. Notice how in Vienna bread the batter sponge is beaten and worked, and how much more vigorous and "lively" it is in consequence.

Temperature.—This governs all; with low temperatures yeast works very slowly, if at all, and with higher temperatures fermentation is accelerated.

Next, as to **conditions retarding fermentation**: these may be summed up as the opposite of the accelerating agents—yeast, weak or in small quantities; hard, dry flours; stiff, unaerated doughs; low temperature; and finally, the addition of salt, which has a very marked retarding effect.

By modifying one or more of these conditions, the baker is able to regulate the speed of his fermentation; and, where certain of them are altered by causes beyond his control, is able to more or less compensate the disturbance by introducing changes in one or more of the others. Suppose, for example, the working of a sponge is unduly hastened by having to use a softer flour than usual, this may be modified by making it tighter, or working with less yeast, or at a lower temperature. A good deal of the art of the baker consists in properly adjusting these variable factors so that they shall properly balance each other, and all conduce to the production of a good loaf of bread.

494. Quick *versus* **Slow Fermentation.**—This is probably a convenient place to make some reference to the relative merits of quick as against slow fermentation processes. One fact revealed by the record of modern methods given in paragraph 477 is that as a whole the various operations of baking have been materially shortened during the past few years. Reference is made in a subsequent paragraph, No. 497, to some experiments on the comparative effect on acidity production of working at comparatively high and low temperatures. The lesson taught by these experiments is that for the same amount of alcoholic fermentation a comparatively high temperature is at least not more productive of acidity than a much lower one. These tests were taken as the starting point of an investigation by one of the authors into the broader question of the effect of speed on bread-making processes generally. The results, of which the following is a *resume,* were published in 1897. The various baking tests were made by Mr. Ellis, an experienced baker, who was then a student in the authors' laboratory.

A London "whites" flour was taken and worked throughout by means of ferment and dough method. All the water and sufficient of the flour were taken to form a batter ferment, the remainder of the flour being used in the dough.

	Quantities in Grams.			
	1.	2.	3.	4.
Flour	560	560	560	560
Water	320	320	320	320
Yeast	5	5	5	15
Salt	6	6	6	6
Temperature of water	70° F.	80° F.	85° F.	115° F.
Time taken to oven ..	13 hrs.	10½ hrs.	10 hrs.	3 hrs.

(Note, 560 grams are about equal to 20 ounces. If these quantities throughout be halved they give in every case lbs. to the sack of 280 lbs.)

REMARKS ON WORKING.

No. 1. Ferment started at 8.0 a.m., well risen by 12.35, dropped 4.20 p.m., dough made 4.35, ripest at 7.10, handed up 8.5, least spring. When baked was closer in pile, good colour crumb, few small holes, not quite equal in sheen to No. 4; crust thin, rather dull in colour.

No. 2. Ferment started at 10.20 a.m., dropped 5.0 p.m., doughed 5.5, handed up 8.20, fairly springy. When baked, was best loaf of those slow worked. Good pile and colour, crumb better texture than others. Nice coloured crust, good appearance, and best shaped.

No. 3. Ferment started 10.35, dropped 4.15, doughed 4.30, handed up 8.10, moulded well, fairly springy, good colour crumb, fair sheen, very sweet to smell and taste, not quite so good a texture or appearance in crust as others.

No. 4. Ferment started at 10.0 a.m., dropped at 11.30, made up 11.37, skin just cracking 12.32 when handed up, moulded 12.50. Much the boldest and best when baked, good pile, good crumb, few small holes, rather best sheen, not quite so sweet to smell, but nicer flavour to palate than No. 1. Crust thin and good colour, although well baked.

In the following table the working character and keeping qualities are summarised. Percentages are also given of acid reckoned as lactic acid, sugar reckoned as maltose, and soluble matter in the breads.

No.	Character in Working.	Keeping Quality and Flavour.	Sweetness.	Acidity.	Maltose.	Soluble Matter
1	Very little spring, dead to handle all the way through.	1st. day—Slightly drier than No. 4. Not so good flavour. 4th. day—Considerably the driest when cut. 6th. day—Much the driest.	Smells sweet.	0.18	0.32	6.04
2	Fairly springy, moulded well.	1st. day—Rather moister than 1 or 4, and better flavour. 4th. day—Keeps its moistness. 6th. day—Has not kept its moistness as well as No. 4 for the longer time.	Sweetest to smell and taste.	0.20	0.35	4.28
3	Rather more springy than No. 2, but not so good as No. 4, handled well.	1st. day—The moistest. 4th. day—Kept much moister. 6th. day—About as moist as No. 4. Sweeter in flavour.	Very sweet.	0.18	0.28	5.68
4	Handled well; full of spring.	1st. day—Rather moister than No. 1. 4th. day—Much the moistest. 6th. day—Moistest and good flavour. The pleasantest flavour of all.	Does not smell so sweet.	0.19	0.10	5.28

The general conclusions to be drawn from this series of experiments is in favour of the quick fermentation method. It is somewhat curious to find that the long fermentation loaf dried off the quicker, especially as there is a somewhat widespread opinion that short fermentation bread loses its moisture the more rapidly.

In the next place experiments were made with larger quantities; straight doughs being employed, in order to determine the minimum of time in which they could be satisfactorily fermented. The following are particulars of quantities and temperatures:—

	1.	2.	3.	4.
280 lbs. of flour at	72° F.	70° F.	68° F.	70° F.
Water at	85° F.	95° F.	112° F.	105° F.
Yeast	20 oz.	19 oz.	18 oz.	22 oz.
Salt	3 lbs.	3 lbs.	3 lbs.	3 lbs.
Temperature of dough when made,			91° F.	

REMARKS ON WORKING.

No. 1 was taken 5 hours after being made, and set in oven in another 50 minutes. Loaf of good appearance and very sweet. Dough might have been taken half-an-hour sooner without injury.

No. 2. Taken 3¾ hours after making, and set in oven in another 50 minutes. Good bold loaf, no foxiness, very sweet.

No. 3. Made 2 quarts of water slacker than No. 2. Fifteen pounds of flour were reserved and dusted in when the dough was cut back at the end of 2 hours. Taken 3 hours after making. Loaf small and runny, probably rather more time required.

No. 4. Taken at end of 3 hours, in oven in 3¾ hours. Bread small and rather flat.

A repeat was next made of No. 2, with the result that the loaf was in every way satisfactory and compared favourably with bread made from the same flour by a long system of fermentation.

The whole of these were fairly stiff doughs for crusty cottage bread, probably the same degree of stiffness as is employed in London for bread of this kind. It was found that a working time of 3½ to 3¾ hours was the best to employ, as when an effort was made to get down to 3 hours the bread fell off in quality. Endeavours were made to shorten the time, both by raising the temperature and increasing the yeast, but the results in neither case could be considered encouraging. No doubt with slacker doughs such as are made for tinned bread, the time might still further be shortened. The flour used was a hard mixture and required to be fermented sufficiently to be free working, and not yield a pinched loaf. Softer flour again would work through in less time. The conclusions drawn were that in appearance and general character at least as good a loaf can be obtained by quick as by slow fermentation processes. The subsequent adoption of quick processes by so large a proportion of bakers is an ample justification of the forecast of 1887.

495. Summary of Course of Fermentation.—A very useful lesson may be learned by making a batch, say of 20 lbs. of flour, into a slack dough, with a full allowance of distillers' yeast, say 3 ounces; salt and water in proportion, and working the batch fairly warm. Let a piece be cut off and moulded into a loaf immediately the dough is made and at once baked—the result will be a close, small, very moist loaf, not much bigger than the piece of dough cut off. Next bake a similar loaf from the same piece of dough at the end of every hour from the time of starting, keeping the main mass covered, and in a warm place. An instructive series of changes will be observed in the successive loaves. In boldness the bread improves for some hours, then remains stationary, and finally becomes "runny" and flat. The colour of the crust is at first "foxy," then of a golden yellow or brown tint, and finally abnormally pale. The crumb during the first three or four loaves of the series gradually improves, and becomes more bloomy, then changes to a greyish white, losing the bloom, and then "saddens" and darkens, becoming a dull, cold grey, merging ultimately into a brown. At the same time it becomes ragged on the outside edges, and dark where a soft crust has been produced by two loaves being in contact with each other in the oven. In flavour, the first loaf will be sweet, but "raw" and "wheaty," characters which will be lost as fermentation proceeds; at its best the raw taste will have gone, leaving only a sweet clean-palate flavour. This will be succeeded by a gradual disappearance of the sweetness, the bread being neutral and tasteless: at the same time the loaf will have lost its moisture, and will be harsh and crumbly. As fermentation is pushed still further, the bread commences to be "yeasty" (to taste of the yeast); but this depends somewhat on the original soundness or otherwise of the yeast. This condition merges into one of slight sourness, first of pure lactic acid flavour, accompanied by buttermilk odour; but gradually becoming worse, until, finally, not only is the taste offensive, but so also is the smell, partaking not only of sourness in character, but also of incipient putrefaction and decomposition. During these latter stages the bread again becomes soft and clammy. The first drying off, until the bread reaches the harsh stage, is due to the disappearance of soluble starch and dextrin by diastasis into sugar, and then fermentation: the subsequent clamminess is the result of degradation, not only of a portion of the starch, but also the insoluble proteins of the dough.

Such are, in brief, the changes observable in dough under ordinary conditions of working, from the first start of fermentation to the commencement actually of putrefaction. These may be slightly modified by character of the flour and other constituents of the dough; but if the conditions of fermentation be healthy and normal, the whole series of changes substantially follows the order given here. **Changes in temperature, degree of stiffness of doughs, etc., within recognised and approved limits, may accelerate or retard fermentation as a whole, but they do not alter its character and general course.**

SOUR BREAD.

496. Souring of Bread.—When dough has been allowed to overwork a frequent consequence is that the resultant bread is sour. Among the earlier views of the causes of such sourness was that which regarded it as being due to the oxidation of alcohol. A fully worked sponge or dough contains considerable quantities of that substance, and it was argued that the well-known change of alcohol into acetic acid by oxidation,

$$\underset{\text{Alcohol.}}{C_2H_5HO} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Acetic Acid.}}{HC_2H_3O_2} + \underset{\text{Water.}}{H_2O},$$

was the cause of the acidity of sour bread, especially from overwrought sponges or doughs.

It will be convenient at this early stage to differentiate between "acidity" and "sour bread," using each of these terms in their generally accepted sense. "Acidity" is a chemists' term and is caused by the presence of free acid; the measure of acidity is the amount of alkali of definite strength required to produce neutrality. "Sour bread" is a baker's term, and is applied to bread which has a sour odour and flavour to the organs of smell and taste respectively. Experiments show that *acidity,* as measured by chemical means, and *sourness,* as judged in bread by the nose and palate, are not necessarily alike in intensity or entirely dependent on each other: for this reason the limitation of the sense in which the authors personally use each term is here indicated.

An explanatory remark may be appropriately introduced here as to the acidity of flour. In dealing with the composition of malt, paragraph 280, it is stated that although its acidity is usually returned as lactic acid, yet a considerable amount is due to the presence of acid phosphates. Now the mineral content of flour contains about 50 per cent. of P_2O_5, and corresponds very closely with the acid phosphate of potassium, KH_2PO_4, so that the acidity of flour is also partly due to the presence of acid phosphates. Balland, again, paragraph 453, points out that acidity develops in flours as a result of age in consequence of the increase of the fatty acids. Notwithstanding this, as with malt, the acidity is commonly returned as lactic acid. It is the developed acidity, and not the normal, which points to unsoundness in both malt and flour, as well as bread; and hence the custom of reckoning such acidity in terms of one of its causes, viz., lactic acid. The normal acidity of flour is largely of mineral origin, its *sourness* and that of bread are the result of the production of organic acids.

As opposed to what may be called the acetic acid hypothesis, it must be remembered that yeast has a great avidity for oxygen, and according to Pasteur's view alcoholic fermentation was a starvation phenomenon in the absence of oxygen. This theory is no longer tenable, but in any case the fact remains that yeast readily absorbs oxygen from any fluid in which it is actively at work. As the acidity of a sponge or dough is the effect of acid fermentation following the normal alcoholic, there cannot be within the mass of dough any oxygen by which the alcohol disseminated through it can be oxidised to acetic acid. For this reason, therefore, it is only on the surface of the dough exposed to air that such action is possible. And even here it must be exceedingly superficial, for in the presence of the possibly slow, but continuous, exhalation of gas *from* the sponge, it is very improbable that any perceptible absorption of oxygen is occurring. Even when quiescent, it must be remembered that a sponge contains an abundance of yeast ready to start again in active fermentation as soon as supplied with food. There will therefore be on the surface of such a sponge yeast in far greater plenty than acetic acid germs, and with the greater vigour of the former organism, it is a fair assumption that of the very limited amount of surface assimilation of oxygen, the lion's share will be taken by the yeast and converted into carbon dioxide. As both lactic and butyric acids are products of anaerobic ferments, and are the result of chemical changes which are absolutely independent of external free oxygen, the same objections do not apply to these as sources of acidity. For these very cogent *a priori* reasons, the authors have viewed the presence of acetic acid as being (under any normal conditions such as are commonly found in a bakery) an exceedingly limited and practically negligible cause of acidity.

497. Personal Researches.—The authors have devoted much attention, both in the bakery and also the laboratory, to this problem of sour bread, and have made a number of experiments of which an account of some of the more important follows.

As a preliminary to the analyses, various tests were made on the methods themselves. It is obvious that the separation of lactic from acetic and butyric acids by the process of distillation is only trustworthy on the assumption that under the conditions of the estimation, lactic acid is non-volatile. But in Miller's *Elements of Chemistry* (*Armstrong & Groves*), it is stated that "*on distilling an aqueous solution of lactic acid, a certain amount of acid volatilises with the steam.*" In order to investigate this point, the following experiments were made:—A sample of lactic acid was taken, which had been sold as chemically pure; this was tested for acetic and butyric acids, but gave no indication whatever of a trace of them being present. This was diluted with pure distilled water, free from carbon dioxide, and absolutely neutral to phenolphthalein, until of a strength equivalent to 7/10 of that of centinormal acid. In a distilling apparatus, consisting of a Wurtz flask and glass (Liebig's) condenser, 110 c.c. of this dilute acid was subjected to distillation until 100 c.c. had come over: the distillate on titration possessed an acidity equal to 2.1 c.c. of centinormal acid. The residuum in the flask when titrated was found to require 63.3 c.c. of centinormal soda. In another experiment the original acidity was equivalent to 45 c.c., that of the 100 c.c. of distillate to 3.7, and that of the residual 10 c.c. to 35.1 c.c. of centinormal acid. In the one case about a thirty-seventh, and in the other a twelfth, of the total lactic acid had come over with the distillate. It may be taken as a general result that, working with very dilute acids, the quantity of lactic acid found in the distillate is not very large, but it is to be feared that it is liable to obscure conclusions based on Duclaux's system of fractionation. It will be noticed that in these experiments there is a considerable loss of acid, as the sum of the acidity of the distillate and the residuum does not agree with that of the quantity of acid originally taken. In order to determine whether there was any loss by a portion of the acid escaping condensation, the apparatus was fitted with nitrogen bulbs containing centinormal soda. In a number of experiments higher and more regular results were thus obtained, showing that some of the acid escaped as steam. This was particularly noticeable when the distillation was accompanied by "bumping." Still the amount of loss thus accounted for was nothing like sufficient to cover the whole of the deficiency.

A further investigation was made as to the reaction to acids of the flasks themselves, and it was found that the alkalinity of a number of flasks was more than sufficient to entirely vitiate the result of experiments made with them. Thus, for the purpose of testing, 110 c.c. of distilled water, free from carbon dioxide and neutral to phenolphthalein, were distilled in a Wurtz flask until reduced to 10 c.c. This residuum was titrated, and required 13.6 c.c. of centinormal acid. Another 110 c.c. of the same water was boiled down in a platinum basin, and the remaining 10 c.c. titrated: 0.1 c.c. of *N*/100 acid produced distinct acid reaction. New flasks are found to yield a much larger quantity of alkali to water than old, and no doubt the glass of some flasks is far more soluble than that of others. Thus a new 400 c.c. Wurtz flask was washed thoroughly, rinsed in dilute sulphuric acid, then washed with distilled water, and attached to a "return condenser" (see fat determination, Fig. 83, Chapter XXII). In the flask were placed 250 c.c. of distilled water, 3 drops phenolphthalein, and 1 c.c. of decinormal acid. The leading tube of the flask was closed, and the water caused to boil until a pink colouration appeared. Another c.c. of decinormal acid was then added and the boiling continued, this operation being several times repeated. The following are the results:—

1st. c.c. of acid was neutralised by alkali dissolved from flask in	35 minutes
2nd c.c. of acid " " "	28 "
3rd. c.c. of acid " " "	37 "
4th. c.c. of acid " " "	45 "
5th. c.c. of acid " " "	40 "

In the next place a flask of "Jena Utensil Glass" was similarly tested. One c.c. of decinormal acid was added to water, as before, and the boiling continued for 2½ hours; at the end of which the contents of the flask were titrated, and found to possess an acidity of 0.5 c.c., showing that only 0.5 c.c. of decinormal acid had been neutralised in that time.

The following experiment may now be described:—A mixture of one part "Red Dog" flour with four of baker's grade spring American flour was made. There were taken 3 lbs. of this mixture, ¾ oz. distillers' yeast, ½ oz. salt, and very warm water. A sponge was first made, which had a temperature of 109° F., afterwards a dough which stood at 84° F. The sponge and dough stood altogether 24 hours in a warm place, and then smelt sour and incipiently putrescent. During the time of standing it was freely exposed to the air, and several times was "handed up" so as to work the outer skin into the mass of the dough.

At the end of this time a portion of the dough was reserved for direct tests, and the remainder baked slowly in a slack oven. (The object of the whole of the treatment was, of course, to get as sour a sample as was well possible.)

Dough.—To determine total acidity 10 grams of the dough were taken, broken down with neutral distilled water and titrated with $N/10$ soda and phenolphthalein (this indicator was used throughout):—required, 10.9 c.c. = 0.981 per cent. of total acidity, reckoned as lactic acid.

For the subsequent tests 50 grams of dough were taken and made up to 400 c.c. with distilled water, 1 c.c. of chloroform having been added. This was thoroughly mixed by repeated shakings, and allowed to stand over night: of the clear supernatant liquid, 230 c.c. were pipetted off the next morning. In 10 c.c. of this the acidity was determined, being equivalent to 11.8 c.c. of centinormal acid. Of this liquid, 110 c.c. were taken and subjected to distillation by Duclaux's method in a "Jena" flask: the liquid frothed so that distillation could only be conducted with extreme slowness, occupying altogether about 2 hours. The following are the results:—

1st.	10 c.c. distillate,	0.35 c.c.	$N/100$ acid	= 3.6%	of total distillate.
2nd.	"	0.45	"	= 4.7	" "
3rd.	"	0.55	"	= 5.7	" "
4th.	"	0.55	"	= 5.7	" "
5th.	"	0.60	"	= 6.2	" "
6th.	"	0.60	"	= 6.2	" "
7th.	"	1.05	"	= 10.9	" "
8th.	"	1.70	"	= 17.7	" "
9th.	"	1.75	"	= 18.2	" "
10th.	"	2.00	"	= 20.8	" "
11th.	in flask	115.4			

Total acidity of 110 c.c. = 129.8; total acidity of distillate = 9.6; acidity of residuum = 115.4; loss, 129.8 — 125.0 = 4.8 c.c. (The same flask evolved, in the blank experiment, alkali equivalent to 5.0 c.c. of $N/100$ acid in 2½ hours.)

These results not only afford no evidence of the presence of butyric acid, but are even lower in the early stages than those of pure acetic acid. It seems probable that with the very slow rate of distillation absolutely necessary, the acid in the earlier stages recondenses in the upper parts of the flask, and so the proportion distilled over does not conform to Duclaux's table. Another 110 c.c. of the same 230 c.c. of liquid was evaporated to dryness in a platinum basin over a water bath, re-diluted with 50 c.c. of water, and again evaporated to dryness: the residual acidity was equivalent to 113.5 $N/100$ acid. The division of acid in this liquid into fixed and volatile agrees closely in both tests. Taking that in the platinum basin as being the more correct, we have out of 129.8 of total acidity, 113.5 of fixed, and 16.3 c.c. of volatile acidity. Reckoning these as percentages on the whole dough, we have in solution 0.74 of fixed acid (lactic) and 0.07 per cent. of volatile (acetic) acid. In strictness, it must also be remembered that any carbon dioxide present in the dough is also estimated as acetic acid, making this result too high rather than too low. Bearing in mind Balland's investigations, Chapter XXIII., in which he shows that a considerable quantity of the acid of flour is retained by the solid matter, and not given up to a filtered solution, the acidity of the remaining 170 c.c. of mixed liquid and residual flour solids was also determined. This was found to contain acid equivalent to 275 c.c. $N/100$ acid. As dough contains approximately 42 to 45 per cent. of water, the 50 grams taken will contain about 50 — 22 = 28 grams of solid matter. Therefore the residual 170 c.c. will consist of about

170 — 28 = 142 c.c. of liquid and 28 grams of solid residue: and the total 400 c.c., of 372 c.c. of liquid and 28 grams of solid. But as the residual 170 c.c. contains 142 c.c. of liquid, the acidity of which is 1.18 per c.c. (by direct determination), then

142 × 1.18 = 167.5 c.c. acidity due to the liquid portions.

Its total acidity, 275 — 167.5 = 107.5 acidity remaining in the solid matter. Calculating this as lactic acid,

107.5 × 0.0009 × 2 = 0.193 per cent. of acid remaining in solid matter.

The 372 c.c. of solution must contain, as by estimations on 110 c.c., the following quantities of fixed and volatile acid:—

$$\frac{113.5 \times 372 \times 0.0009 \times 2}{110} = 0.792 \text{ per cent. fixed acid reckoned as lactic.}$$

$$\frac{16.3 \times 372 \times 0.0006 \times 2}{110} = 0.066 \text{ per cent. volatile acid reckoned as acetic.}$$

Summing up these results we have—

Dissolved fixed acid (lactic)	0.792	per cent.
Dissolved volatile (acetic)	0.066	"
Undissolved acid, remaining in solids	0.193	"
	1.051	
Total acidity by direct determination ..	0.981	
Difference	0.070	

Bread.—In common with the dough, the bread smelt not only sour, but of putrefactive products. The first estimation made was of moisture, of which there was 40.4 per cent., leaving 59.6 per cent. of dry bread solids. The percentages of acid are given on both the moist and dry bread. The total acidity was determined on 10 grams, and amounted to 10.1 c.c. of $N/10$ acid = 0.912 per cent. of acid reckoned as lactic acid on the moist bread. It may be of interest here to point out that 10 grams of dough = 10.9 c.c. of $N/10$ acid, and that approximately 10.6 grams of dough are required to make 10 grams of bread.

10.6 grams of dough have an acidity	= 11.55 c.c. $N/10$ acid.	
10.0 " bread "	= 10.10	"
Acidity lost during baking	= 1.45	"

1.45 × 0.006 = 0.0087 grams acetic acid.

By this estimation, therefore, the bread has lost of acidity, reckoned as acetic, 0.08 per cent. As the bread still contains volatile acidity, and this amount is slightly less than the volatile acidity of the dough, the assumption is that a slight amount of lactic acid has been volatilised in the oven.

An aqueous extract of the bread was made in precisely the same manner as with the dough, 50 grams being taken and made up to 400 c.c. with the addition of 1 c.c. of chloroform. The following data were obtained on the clear supernatant liquid, of which 220 c.c. were removed:

Total acidity of 10 c.c. = 9.3 $N/100$ acid.

110 c.c. were subjected to distillation by Duclaux's method, and boiled regularly and speedily. The following are the results:—

1st.	10 c.c. distillate,	0.80	c.c. $N/100$ acid	= 6.5%	of total distillate.
2nd.	„	0.85	„	= 6.9	„ „
3rd.	„	0.85	„	= 6.9	„ „
4th.	„	0.95	„	= 7.7	„ „
5th.	„	1.10	„	= 9.0	„ „
6th.	„	1.10	„	= 9.0	„ „
7th.	„	1.25	„	= 10.2	„ „
8th.	„	1.45	„	= 11.7	„ „
9th.	„	1.65	„	= 13.5	„ „
10th.	„	2.20	„	= 17.2	„ „
11th. in flask		90.7			

Total acidity of 110 c.c. = 102.3; total acidity of distillate = 12.2; acidity of residuum = 90.7; gain, 102.9 — 102.3 = 0.6 c.c. of $N/100$ acid.

These results are not very far apart from acetic acid, but are slightly on the formic rather than the butyric acid side.

100 c.c. were evaporated in a platinum basin, and gave 79.0 c.c. $N/100$ acidity, equal to 86.9 on 110 c.c. 102.3 — 86.9 = 15.4 c.c. of volatile acid. Working these out as percentages of lactic and acetic acids, we have 0.626 of lactic and 0.075 of acetic acid on the whole bread.

The residual liquid together with bread solids was next examined: the total volume was 400 — 220 = 180 c.c. As 50 grams of bread were taken, the bread solids were 30 grams. Therefore the residual 180 c.c. consisted of

180 — 30 = 150 c.c. of liquid and 30 grams of solids, and the total 400 consisted of 370 c.c. of liquid and 30 grams of solid.

The total acidity of the residual liquid and solids together is 306.0 c.c. $N/100$ acid. But as this contained 150 c.c. of liquid, the acidity of which is 0.93 per c.c., then

150 × 0.93 = 139.5 c.c. acidity due to the liquid portion.

The total acidity, 306.0 — 139.5 = 166.5 acidity remaining in the solid matter. Calculating this as lactic acid,

166.5 × 0.0009 × 2 = 0.299 per cent. of acid remaining in solid matter.

The 370 c.c. of solution must contain, as by estimation on 110 c.c., the following quantities of fixed and volatile acid:—

$$\frac{86.9 \times 370 \times 0.0009 \times 2}{110} = 0.526 \text{ per cent. fixed acid reckoned as lactic.}$$

$$\frac{15.4 \times 370 \times 0.0006 \times 2}{110} = 0.062 \text{ per cent. volatile acid reckoned as acetic.}$$

Summing up these results, we have—

Dissolved fixed acid (lactic)	0.526	per cent.
,, volatile acid (acetic)	0.062	,,
Undissolved acid remaining in solids ..	0.299	,,
	0.887	
Total acidity by direct determination ..	0.912	
Difference	0.025	

Distillation in Vacuo.—In the next place, 500 grams of the bread were taken and distilled in vacuo, the bread being raised to a temperature of 120-125° C. The amount of distillate was 220 c.c., of which 10 c.c. were taken for determination of total acidity, and were found to possess acidity equal to 11.4 c.c. $N/100$ acid. Ten grams of the residual dry bread had an acidity equal to 16.0 $N/10$ acid. Calculated as percentages on the whole bread, these are equivalent to 0.30 per cent. of volatile (acetic) acid, and 0.864 per cent. of fixed (lactic) acid.

Of the distillate, 100 c.c. were evaporated to dryness in a platinum basin and taken up with distilled water; the addition of one drop of $N/100$ soda gave an alkaline reaction with phenolphthalein, showing that the distillate was to this extent free from fixed acid The remaining 110 c.c. were distilled by Duclaux's method in a "Jena" flask, with the following results:

	N/100 acid =	A. Per cent. of = total distillate.	B. Per cent. of total acid in 110 c.c.
1st. 10 c.c. distillate	5.80 c.c.	6.4	4.6
2nd. " "	6.60 "	7.3	5.3
3rd. " "	7.70 "	8.5	6.2
4th. " "	8.30 "	9.2	6.6
5th. " "	8.40 "	9.3	6.7
6th. " "	8.80 "	9.8	7.1
7th. " "	9.65 "	10.7	7.7
8th. " "	9.80 "	10.9	7.9
9th. " "	11.35 "	12.6	9.1
10th. " "	13.50 "	15.0	11.0
11th. in flask	34.35 "	—	27.9

Total acidity of 110 c.c. = 125.4; total acidity of distillate = 89.9; acidity of residual 10 c.c. = 34.35; loss, 125.4 — 124.25 = 1.15 c.c. of $N/100$ acid.

A reference to tables of distillation of mixtures of acetic and butyric acids by Duclaux's method shows that the figures in column A agree closely with those for a mixture of 20 parts acetic to 1 part butyric acid, being distinctly on the butyric acid side of pure acetic acid. It may be considered proved that a trace of butyric acid is present equal to approximately 1/20 of the amount of acetic acid.[1]

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[1] Duclaux points out that with the use of a larger distilling flask a higher proportion of acid remains in the residual 10 c.c., that is, that with a greater proportion of return condensation, more acid escapes distillation. As slow distillation also means more return condensation, the same result follows. The use of charged trap-bulbs with the distilling apparatus, necessitated slow working; hence the general error of experiment is in the direction of lessening the apparent quantity of butyric acid.

Calculating into percentages, we have of the total acidity,

$$\frac{125.4 \times 20}{21} = 119.4 \text{ c.c. } N/100 \text{ acid due to acetic acid;}$$

$$\frac{125.4}{21} = \quad 6.0 \text{ c.c.} \quad ,, \quad \text{butyric acid.}$$

Then as 110 c.c. of distillate were obtained from 250 grams of bread,

$$\frac{119.4 \times 0.0006 \times 2}{5} = 0.028 \text{ per cent. of acetic acid in whole bread,}$$

$$\text{and } \frac{6.0 \times 0.00088 \times 2}{5} = 0.002 \text{ per cent. of butyric acid in whole bread.}$$

Summing up, we have the following as the general results of the different analyses, expressed in percentages, those on bread being calculated on both the whole bread and dry residue:—

		Bread.	
	Dough.	Whole.	Dried.
Total acidity by direct determination	0.981	0.912	1.521
Dissolved fixed acid (lactic) ..	0.792	0.526	0.876
Dissolved volatile acid (acetic) ..	0.066	0.068	0.103
Undissolved acid, remaining in solids	0.193	0.299	0.498
Distillation in Vacuo—			
Fixed acid (lactic)		0.864	1.440
Volatile acid (acetic)		0.030	0.050
Fractional Redistillation of Vacuum Distillate—			
Acetic acid		0.028	0.047
Butyric acid		0.002	0.003

Comparing the results of the two different methods of analysis employed, we find that with aqueous distillation about 1/15 of the total acid in both dough and bread was found to be volatile. Employing the dry distillation method on bread, 1/30 of the total acid was volatile at 120° C. *in vacuo.* As to the relative accuracy of the two processes, the former presents the initial difficulty that the whole of the acid is not obtained in the aqueous extract; and, further, that a portion at least of the lactic acid distils over with the steam. It may, on the other hand, be objected that the whole of the acetic acid is not volatilised by the treatment *in vacuo.* Weigert, however, has shown that by distilling wines in a vacuum, the whole of the acetic acid can be obtained (*Zeitsch, für Analyt Chemie.,* 1879, 207). A number of other comparative determinations were made, but in all cases the aqueous extract method gave considerably higher volatile acids than distillation *in vacuo.*

The following experiments were conducted with the view of studying the progress of sourness with the prolongation of fermentation:—

A. Series.—Quantities taken—15 lbs. spring American 1st patent flour, 9 lbs. water at 40° C. (104° F.), 4 oz. compressed distillers' yeast, and 2 oz. salt.

A ferment was first set with all the water and a portion of the flour: in 40 minutes the dough was made, and had a temperature of 27° C. (80° F.). It was maintained at this temperature for 20 hours, and then allowed to stand at the temperature of the room for another 24 hours. At intervals, as given in the following table, the dough was "knocked down," re-kneaded, and a portion of 2 lbs. 3 oz. taken and baked into a loaf.

B. Series.—Quantities taken—12 lbs. spring American bakers' grade and 3 lbs. low grade (red dog) flour, other ingredients as in A. Treatment precisely as in A.

The following are the times at which loaves from both series were baked:—

No. 1. Put in oven 3½ hours after setting ferment.
„ 2. „ 6 „ „
„ 3. „ 9 „ „
„ 4. „ 12 „ „
„ 5. „ 15 „ „
„ 6. „ 20 „ „
„ 7. „ 44 „ „

The following were the characteristics of the respective loaves:—

A. SERIES.

No. 1. Sweet in smell and taste.
„ 2. If anything, slightly darker in colour; slightly mawkish smell and taste, not sour or yeasty, crust paler.
„ 3. Colour darker, mawkish flavour disappeared, incipient sour smell, but no sour taste.
„ 4. Colour darker, loaf heavy and close, somewhat yeasty smell, but no decided sour flavour.
„ 5. Small and close, colour about same as 4, sour smell; taste, acid and disagreeable.
„ 6. } Sour and putrescent.
„ 7. }

B. SERIES.

No. 1. Characteristic odour of bread from low grade flours, but perfectly sweet in taste and smell.
„ 2. Colour very dark, sour smell, taste slightly sour.
„ 3. Colour changed from yellowish to dark reddish brown. Less sour smell than 2. Unpleasant taste, rather of decomposition than acidity.
„ 4. Reddish brown colour much intensified. Slightly sour smell. Taste similar to 3, but more marked.
„ 5. Colour as 4. Smell and taste intensified.
„ 6. Sour and putrescent.
„ 7. Sour and putrid.

None of these had the characteristic sour smell of *bakers'* sour bread.

The following are the results of determinations of acidity, the total being determined on the whole bread; the volatile by distillation in vacuo; and the fixed or non-volatile, in the dried residue from this distillation.[1] As the moisture in the different samples varied, the results are throughout calculated on the dry solids. These can be approximately converted into those on the whole bread by multiplying by 0.6.

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[1] The whole of these distillates were subjected to fractional distillation by Duclaux's method. Owing, however, to subsequently finding that the flasks used gave a strong alkaline reaction, the authors do not feel justified in quoting the results as trustworthy, and therefore have not inserted them. The same remark applies to a large number of other Duclaux estimations.

PERCENTAGES OF ACIDITY IN SOUR BREAD.

No.	A. Series. Total.	Volatile.	Fixed.	Ratio of Volatile to Total.	B. Series. Total.	Volatile.	Fixed.	Ratio of Volatile to Total.
1	0.477	0.003	—	1/160	1.140	—	1.125	—
2	0.407	0.015	0.405	1/27	1.041	0.042	0.972	1/25
3	0.491	0.030	0.441	1/16	1.300	0.102	1.143	1/12
4	0.671	0.090	0.549	1/7	1.647	0.252	1.269	1/7
5	1.108	0.120	0.720	1/9	2.289	0.128	1.314	1/17
6	1.110	0.087	0.747	1/12	2.600	0.113	1.746	1/23
7	1.457	0.059	0.900	1/24	2.828	0.131	1.980	1/21

Curiously in both series the total acidity is less in the second than in the first loaf: with this exception the total acidity steadily rises throughout the two series. The volatile acidity (reckoned as acetic) attains its maximum in Series A. in 12 hours, and in series B. in 15 hours, after which it diminishes. The ratio of volatile to total acidity is in both cases highest with the No. 4 loaf. Apparently after that time the production of volatile acid does not keep pace with its evaporation from the dough. (It should also be mentioned that, as the loaves were analysed in the order made, the latter ones had become somewhat drier when subjected to analysis.) In consequence of the dark colour of the dried bread, the determination of fixed acid was difficult owing to uncertainty as to the exact point of neutrality as shown by the indicator. In these breads No. 2's are worked more than the baker would work them in actual practice; while No. 3 of each series is far sourer than even a *baker's very sour* loaf. The others, of course, represent extreme results altogether outside those of actual practice. Note that in No. 3 A. the volatile acidity is only 1/16 of the total, and in No. 3 B. 1/12 of the total acidity.

In the next place are given the results of an experiment with a potato ferment, purposely allowed to proceed to *extreme* sourness. A potato ferment was made from 30 grams of potato, 100 grams of water in which the potato was boiled, 5 grams raw flour, and 10 grams of yeast. This was fermented at 95° F., and maintained at that temperature over night in an uncovered shallow basin. The next morning the ferment was made up to 300 c.c., with water at 120° F., and sufficient flour added to make a slack sponge, which had a temperature of 95° F. The total acid reckoned as lactic was determined in 10 grams of the whole sponge, and the volatile and fixed acids in the filtered chloroformed aqueous extract in the manner previously described. The following were the results:—

Total acidity as lactic acid	1.197 per cent.
Dissolved fixed acid (lactic)	0.248 „
„ volatile acid (acetic)	0.053 „
Ratio of volatile to total acid	1/22

The sponge was allowed to work for 6 hours and then doughed up with more flour, allowed to work 1½ hours and baked. The following are the results of determinations on the bread. The total acidity was determined on the whole bread, and volatile and fixed acids by distillation *in vacuo.*

	Whole Bread.	Dried.
Total acidity as lactic acid	1.158	1.935
Fixed acid by distillation *in vacuo* (lactic)	1.015	1.692
Volatile " " (acetic)	0.038	0.064
Ratio of volatile to total acid	1/30	1/30

The principal feature is that again neither in sponge nor in dough is there more than a very small proportion of volatile acid.

Following on these were some experiments made on bakers' breads. One firm in the south of England, and another in Glasgow, were kind enough to reserve a loaf of one batch baked in the usual manner (No. 1), and also to set aside dough for two other loaves, one of which (No. 2) was baked in each case when at the utmost limit of sourness ever found in practice, and the other (No. 3) several hours after. The following are the results of analysis made as before by vacuum distillations, and in filtered, chloroformed, aqueous extract:—

		English.		Scotch.	
		Whole Bread.	Dried.	Whole Bread.	Dried.
No. 1.	Total acidity as lactic acid ..	0.362	0.604	0.258	0.431
	Fixed acid by distillation *in vacuo* (lactic)	0.351	0.585	0.243	0.406
	Volatile acid by distillation *in vacuo* (acetic)	0.0006	0.001	0.005	0.008
	Ratio of volatile to total acid	—	1/604	—	1/50
	Dissolved fixed acid (lactic) by aqueous distillation ..	0.184	0.307	—	—
	Dissolved volatile acid (acetic)	0.009	0.016	—	—
	Ratio of volatile to total acid	1/19	1/19	—	—
No. 2.	Total acidity as lactic acid .	0.535	0.891	0.342	0.570
	Fixed acid by distillation *in vacuo* (lactic)	0.491	0.819	0.324	0.540
	Volatile acid by distillation *in vacuo* (acetic)	0.025	0.042	0.008	0.013
	Ratio of volatile to total acid	1/21	1/21	1/44	1/44
No. 3.	Total acidity as lactic acid..	0.759	1.265	0.342	0.570
	Fixed acid by distillation *in vacuo* (lactic)	0.696	1.161	0.318	0.531
	Volatile acid by distillation *in vacuo* (acetic)	0.036	0.060	0.017	0.028
	Ratio of volatile to total acid	1/21	1/21	1/20	1/20

Throughout this series also the proportion of volatile acid is very low.

Excluding those examples in which acidity was pushed far beyond any instance ever occurring in practice, the volatile acids found by distillation amounted to from 1/20 to 1/30 the total acid of the dough. In the instance quoted of a loaf in the last stage of sourness, an amount of butyric acid was found approximately equal to about 1/20 the total volatile acid. The acidity of bread may be divided among the following acids in approximately the following proportions:—

Lactic acid	about 95 per cent.
Acetic „	„ 5 „
Butyric „	from 0.0 to about 0.5 „

The question has been already raised as to how far the *bakers'* sourness is dependent on the *chemists'* acidity of bread: this problem merits further examination. The particulars of the progressive series of tests given on page 338 should be studied in this connection. Taking first the A. series on patent flour, No. 4 loaf had no decided sour flavour, while No. 5 tasted acid. No. 4 had a total acidity of 0.671, while that of No. 5 was 1.108 per cent., so that a marked increase had occurred. Comparing the B. series, No. 2 was slightly sour with an acidity of 1.041, although No. 1 with a slightly higher acidity was sweet to the taste. It must be remembered that in the B. series the naturally strong coarse flavour of the flour used made it difficult to detect shades of acidity with the palate. Dealing with the smell, No. 3A. was found to have incipient sour smell, with a volatile acidity of 0.030: turning to the B. series, No. 2 has a sour smell with a volatile acidity of 0.042. On studying the higher number of each series there is a steady increase of total acid, but in both A. and B. the volatile acid is lower in these higher numbers. So that 7 A., with an exceedingly sour smell, has less volatile acid than No. 4, which it far transcends in odour. The same applies to the B. series where No. 6 contains practically the same amount of volatile acid as does No. 3, although No. 3 smells less sour than 2, while No. 6 smelt sour and putrescent. Speaking in a general way, sourness and acidity go together, and bread with a total acidity of about 0.5 per cent. and a volatile acidity of about 0.025 begins, especially in the highest class breads, to both taste and smell sour. But lower grade breads can carry a much higher proportion of total acidity, and have its taste masked with the natural strong flavour of the flour. But although sourness and acidity are closely associated, yet the bakers' sourness comprehends more than is expressed by acidity, as is shown by the increasing "sourness" to the nose of Nos. 5, 6, and 7 of both series, and the simultaneously decreasing volatile acidity. As indicated in the description of the various breads, bakers' sourness also includes and takes cognisance of incipient putrefactive changes. If this be the case, "sourness" should be accompanied by evidence of other chemical changes: as proteins break down in putrefaction into compound and simple ammonias, the following determinations were made on bread. Five grams of the bread were taken, broken down in water, and large excess of caustic soda added: the mixture was then distilled in a current of steam and the distillate collected in 50 c.c. of $N/10$ acid. Determinations were made on the three samples of English bread, particulars of which are given on page 340. The following are the percentages of ammonia (reckoned as NH_3), calculated on the whole bread:—

English Bread,	No. 1	0.39 per cent.
,, ,,	No. 2	0.40 ,,
,, ,,	No. 3	0.42 ,,

The amount of increase is not very great, but as a similar increase of ammonia has been noted in other breads tested, evidence is afforded that **bakers' sourness is accompanied by other changes in the constituents of the bread in addition to the development of acidity.**

This question of sourness is of vast importance to the baker, and is also the baking problem on which chemistry has the most direct bearing; it therefore merits most careful attention in all its details. Because lactic and acetic ferments flourish best at a high temperature, it has been assumed that therefore "high temperatures for panary fermentation are in all cases undesirable." The assumption that high temperatures are more usually accompanied by the production of sour bread than lower ones is so directly the opposite of many bakers' practical experience that it requires most careful examination. Among breads which are normally worked at a high temperature, the following are well-known examples:— Nevill's bread, made in London from straight grades of comparatively weak flour; and Hovis bread, made from a meal containing 25 per cent. of germ. The temperature of the dough for the latter is about 90°-95° F., and yet these two varieties of bread are remarkably free from sourness. In preceding paragraphs a summary of the course of fermentation has been given, while high temperatures have been mentioned as accelerating the whole of that course; consequently, at a high temperature, everything else being equal, the sour stage is reached in less time from the commencement of setting a ferment, sponge, or dough, than if a lower temperature be adopted. But if fermentation be arrested at the same stage of its progress, there is no more danger of bread worked warm becoming sour than that which is worked cold. The crucial point as to temperature is whether, for the same amount of carbon dioxide gas evolved during alcoholic fermentation, more acid is produced at a high temperature than a low one. In order to elucidate this point the following experiments were made:—Mixtures were prepared of 50 grams flour, 200 c.c. water, and 2.5 grams distillers' yeast, and 10 grams brewers' yeast respectively. These were placed in the yeast-testing apparatus, Fig. 21, and fermented at the respective temperatures of 75° and 95° F., which in each case were maintained constant until 350 c.c. of gas had been evolved. The original acidity of the mixtures was determined in duplicates made up for the purpose. As soon as the 350 c.c. of gas had been obtained, 2 c.c. of chloroform were added to the contents of the bottle, which was shaken up and allowed to stand until all were ready for titration, when the acidity was once more determined. Two complete series of estimations were made on successive days. In another similar experiment with distillers' yeast the fermenting mixture was first maintained at 95° F. until 175 c.c. of gas had been evolved: it was then cooled to 75° F., and kept at that temperature until 90 c.c. more had come over. The temperature was then again raised, and maintained at 95° until the whole 350 c.c. of gas had been evolved. The following table gives the time required for the evolution of 350 c.c. of gas, the original acidity, the final acidity, and the amount produced during fermentation, reckoned in each case as lactic acid:—

	Time taken. Hours.	Original Acidity.	Final Acidity.	Produced during Fermentation.
Distillers' yeast at 75° F. ..	10½	0.175	0.394	0.219
„ „ 95° F. ..	3½	0.175	0.290	0.115
Brewers' „ 75° F. ..	11	0.228	0.424	0.196
„ „ 95° F. ..	6	0.228	0.442	0.214
Repeats—				
Distillers' yeast at 75° F. ..	11½	0.315	0.540	0.225
„ „ 95° F. ..	4¼	0.315	0.495	0.180
Brewers' „ 75° F. ..	11	0.157	0.679	0.522
„ „ 95° F. ..	5¾	0.157	0.670	0.513
Distillers' yeast, partly at 75° F. and partly at 95° F.	7¼	0.315	0.495	0.180

With the distillers' yeast, in both instances there is for the same amount of alcoholic fermentation a greater development of acidity at the lower temperature; while with the brewers' yeast there is in the one case slightly more acid at 75° F., and in the other a slightly greater quantity at the higher temperature. In passing, attention is directed to the much higher acid-producing power of the brewers' yeast on the second day (with a different sample) than the first. Both the practical experience of the bakery and these tests go to show that **for the same amount of alcoholic fermentation a comparatively high temperature is at least not more productive of acidity than a much lower one.** Further confirmation of this is afforded by the advent of short systems of fermentation in which the dough is worked at high temperatures, and with great freedom from sourness. The last experiment was made with the object of determining whether a sudden lowering of temperature during fermentation had a tendency to increase acidity. The results show that no such increase was caused in this instance.

Slackness of dough is only a cause of acidity in the same sense as high temperature, in that it accelerates the whole course of fermentation. Among breads made from *very slack* doughs are Manchester tin bread and Vienna bread, but neither of these are specially liable to sourness.

Holding the view that much of the acidity of bread is due to acetic acid, and that the production of this acid is stimulated by the presence of oxygen, Briant advises that "therefore fermenting dough should be kept as much out of contact with air as is possible." If the quantity of acetic acid present in doughs which are most intensely sour in character is but trifling, then this reason for exclusion of air no longer exists. To refer again to Vienna bread, the ferments and dough for this are beaten and exposed to air almost as much as an egg in the act of whisking, and these are rarely, if ever, sour. If a baker finds a sponge working too rapidly, and in such a condition as his experience tells him means that fermentation is likely to have overshot the mark by the time he wishes to take it, then, *in order to lessen risk of sourness,* he very commonly throws off the trough lid and freely exposes it to air. He finds practically that this treatment, instead of causing sourness by oxidation of alcohol, obviates it by lowering the temperature, and so retarding the whole course of fermentation.

The following may be taken as a summary of the authors' views on sour bread.

1. "Sour bread," as understood by the baker, is the result of a combination of bacterial fermentations. Principal among these is that producing lactic acid, which constitutes about 95 per cent. of the total acidity. The remainder is due to acetic acid, with, in very bad cases, traces of butyric acid. In addition to the development of acidity, sour, as distinct from acid bread, shows signs of putrefactive decomposition.

2. The acid and putrefactive fermentations are produced by bacteria to be found in the dough.

3. These bacteria may be introduced by the yeast, by the use of dirty vessels, and by the flour; but their presence in the flour is the most general cause of "sourness," and the lower the grade of the flour, the greater is the risk of sour bread.

4. The activity of these bacteria is dependent on that of the yeast: while the latter is active, the bacteria are comparativly quiescent. With the exhaustion of the yeast, or cessation of active fermentation through the assimilation of all fermentable material, a stage is attained in bread fermentation when bacteria are excessively active, and sourness rapidly develops.

5. Temperature and slackness of dough have but little effect on sourness, except in that indirectly they affect the speed of the whole course of fermentation, and so hasten or retard the arrival of the bacterial fermentation stage. This stage being reached, the production of sourness is accelerated both by high temperature and slackness of dough.

6. Exposure to air has no appreciable effect on sourness, and may even through its cooling action be beneficial.

7. The two principal causes of sourness are—Allowing the fermentation to proceed beyond the normal into the souring stage; and the use of materials or vessels containing abnormally high proportions of bacteria, especially when employed with weak and inactive yeasts.

498. **Effect of Baking on Bacterial Life.**—Differences of opinion exist as to whether the act of baking destroys the life of all organisms that may be present in the dough. Unless the baking is most inefficiently

conducted the temperature within the loaf should be sufficiently high to kill the yeast. The doubt is whether or not the germs or spores of other organisms are also destroyed—thus, the spores of some of the *bacilli* can withstand a quarter of an hour's boiling, while a sensible proportion outlive an hour's subjection to a boiling heat. These experiments afford grounds for supposing that such germs might continue to exist even during an hour's baking. The observed facts of the souring of bread also point in the same direction. Two loaves may be taken, each of which is sweet when removed from the oven, and kept under precisely the same conditions; the one after a few hours becomes sour, the other retains its sweetness. Here there is a difference in behaviour which is not due to external conditions, but to some inherent quality of the two loaves. The undestroyed germs of acid fermentation have, in the bread in which they are present, induced sourness. The only other explanation of souring is that the germs of the specific *bacilli* have found their way from the atmosphere into the baked loaf.

Walsh and Waldo subjected this matter to exhaustive investigation. Using the accustomed precautions in bacteriological work, they procured a number of loaves of bread, and sowed portions of the interior crumb in sterilised gelatin and glucose mixture, and made plate cultivations. A few of the loaves were found to be practically sterile, while others contained a large number of organisms, including *bacillus subtilis* and other *bacilli*, also *sarcina* and *micrococcus*. Many of these organisms were unidentified by Walsh and Waldo, but it may fairly be assumed that, with lactic and butyric ferments present in the dough, they may be among those organisms which have lived through the baking. Hence they may set up their characteristic fermentations in the baked bread.

It should be mentioned in passing that Walsh and Waldo base a very powerful argument for sanitation in bakehouses on this fact, that baking does not necessarily sterilise bread. Their view is that if non-pathogenic organisms may thus survive, so may also the pathogenic forms; and so bread, if contaminated during manufacture, may afterwards become a source of infection. Goodfellow finds that, provided the bread be allowed to stand for three hours in a germ-free atmosphere after being baked, the loaf is absolutely sterile. That is, the act of baking, coupled with the continuance of the baking heat on the loaf, for the period of time mentioned, is sufficient to destroy the life of all micro-organisms. If Goodfellow's view be correct, then the position assumed by Walsh and Waldo is no longer tenable.

The conditions of keeping make a considerable difference in the after-sweetness of baked bread. Where bread is kept in a close, warm, moist atmosphere, from the time of baking or when new, it is far more likely to develop sourness and mould than if stored where it may rapidly cool and lose any excess of moisture.

499. Remedies for Sour Bread.—These are to a large extent indicated in the preceding paragraphs, but as one possible cause of sour bread is a want of absolute cleanliness, it should be seen that all the precautions to insure the same are rigidly adopted. Supposing, as is sometimes the case, that batch after batch of bread is sour, or rapidly becomes so; then see that the flour is sound and discard any very low grades; next examine the yeast; see more especially whether disease ferments are plentiful, and whether the yeast-cells themselves look healthy and vigorous. The baker who is not able to do this for himself should place himself in the hands of an analyst to do it for him. If any suspicion whatever attaches to the yeast or the flour, change to some other variety which is known to be doing good work. In the next place, thoroughly clean the bakehouse from floor to ceiling. Procure some solution of bisulphite of lime, and with a brush wash floor, walls, and ceiling with it. Clean out all troughs and boards, and also wash them with the bisulphite, letting it remain in the troughs for some time. Then either scald or steam them out, and dry as rapidly as possible. These steps should succeed in freeing the bakehouse from any disease ferments which may be present.

In conducting fermentation, use a sufficient quantity of good yeast, and work at such a temperature as to get sponging and doughing over quickly.

As souring is largely produced by some cause unduly accelerating fermentation, investigate the whole of these, and modify one or more, according to which seems faulty, so as to retard to the normal rate. Or, if deemed preferable, set later or take sooner so as to use sponges or doughs at the right stage of fermentation. Use regular brands of yeast and flour, watching and adjusting these as may be necessary. Souring, if due to sudden atmospheric changes, is to a certain extent beyond control; but it may be checked somewhat by cooling, if the too quickly working material can be caught in time. The addition of salt to a too rapidly working sponge retards the whole rate of fermentation, and particularly that of *bacteria*. In exceptional cases, through the presence in undue quantities of *bacteria,* and the use of weak yeasts, the fermentation may become abnormal, and "sour" fermentation accompany, or even precede, the full development of normal alcoholic fermentation. Give the bread a good baking, as bread which leaves the oven in a damp, sodden condition is specially liable to become sour. When baked, cool rapidly in a pure atmosphere. Weak, unstable flours used with excess of water very frequently turn sour; the reason is that the gluten breaks down, and much of the starchy interior of the loaf is dextrinised: the damp, clammy mass resulting constitutes a favourable *nidus,* or home, for after-fermentation.

500. Ropiness, Watkins.—One of the most valuable contributions to the bibliography of this subject is a paper on "Ropiness in Flour and Bread, and its Detection and Prevention," read by E. J. Watkins before the Society of Chemical Industry, on April 2, 1906, and published in the *Journal of the Society* for 1906, p. 350. The following is an abstract of this important paper:—

Occurrence.—During hot weather bread is liable to an outbreak of the disease called "rope." Its first manifestations usually occur in from 12 to 48 hours after the bread leaves the oven.

Nature and Symptoms.—The bread acquires a faint sickly odour, and the crumb is infected with brownish spots, which are larger the nearer the centre of the loaf. With the progress of the disease, the spots spread and the interior of the loaf becomes moist and sticky. The infected portions may be drawn out into long threads, and hence the name of rope. With the continuation of the disease, the crumb of the bread breaks down into a molasses-like mass, and emits an exceedingly disagreeable valerian-like odour.

Susceptibility.—Breads containing bran and germ, such as wholemeal, certain patent breads, and rye bread, are all particularly susceptible. Of those made from white flour, the grades composed of the heart of the endosperm, *i. e.,* the best patent flours, are less likely to produce rope than the lower grade flours, which are more or less contaminated with dust and bran fragments.

Origin.—All modern writers agree in ascribing rope to bacterial activity. In the case of liquors, such as beer, the condition of ropiness has been exhaustively examined, and various organisms identified as the active agents. Morris and Moritz have traced ropiness in beer to *Pediococcus Cerevisiae,* while Pasteur has associated it with a small globular organism 0.0012 to 0.0014 mm. in size. Ropy bread has been comprehensively investigated in Germany by Vogel, who isolated two species of bacteria which he identified as belonging to the potato bacilli group, and which he named *B. Panis Viscosus I.* and *B. Panis Viscosus II.* respectively. Other workers also agree in finding potato bacilli in bread.

WATKINS' PERSONAL RESEARCHES.

Cultivation of Organism.—The sticky material from the centre of a ropy brown loaf was removed with a sterile platinum needle and mixed with sterilised water. Nutrient gelatin, agar-agar, sterilised bread, and peptonised wort respectively were inoculated with this solution, and cultivated at 26° C. in the incubator. Growth occurred in all cases, and microscopic examination showed the organism to be a short motile bacillus. This was regrown several times in peptone wort, until a practically pure culture was obtained.

Experiments on Sound Bread.—Sound loaves, two days old, were taken and cut in two with a sterilised knife. On one half three loopsful of the wort culture of the organism were sown, and the bread placed in a moist incubator at a temperature of 28° C. The companion was as a check placed by its side. In four such tests at various temperatures ropiness was found to have developed in the inoculated bread within 12 hours. The temperatures ranged from 28° to 35° C. and the growth of rope was much accelerated by the higher temperatures. In no case did the uninfected portion develop ropiness, though the test was continued until moulds had made their appearance.

Baking Tests.—These were made with a sound patent flour, the materials being mixed in a porcelain trough, and the proportions similar to those in daily use for "straight doughs," *viz.,* 280 grams of flour, 150 grams of distilled water, 5 grams of yeast, 1 gram of sugar, 3.5 grams of salt, thus making a miniature sack batch with a yield of one loaf of about 400 grams. [In passing, it may be pointed out that the yeast is in higher proportion than is used in a sack batch, but no higher than is customary and advisable in making small trial loaves.] The temperature of the dough was about 31° C.; fermentation was allowed to proceed for 2 hours; the dough was then moulded, proved, and baked for 40 minutes at an oven temperature of 204° C. (400° F.). A series of seven such tests was made. In five tests a quantity of water, increasing from 1 to 5 c.c., was taken from the 150 c.c. of doughing water, and replaced by a corresponding quantity of the peptone wort culture of the organism. The fermentation and baking of these loaves proceeded normally, and the resultant bread was light, with a sweet normal odour, flavour and appearance on leaving the oven. The loaves were cut in two with a sterilised knife, and one half of each was placed in the incubator at a constant temperature and in moist air. The check halves were kept at room temperature (14°-18° C.) in a dry atmosphere for seven days, and then for another four days at the same temperature in a damp atmosphere. In every case where the temperature of the loaf was kept below 18° C., and whether in the presence or absence of excessive moisture, there was no development of ropiness. On the other hand, every portion to which any quantity of the culture had been added, became ropy at temperatures between 25° and 30° C. in a moist atmosphere. The presence of the disease could be detected by the characteristic smell long before any other obvious changes in the bread had made their appearance.

Further Temperature Test.—A sound loaf was cut in two and each portion inoculated with 1 c.c. of a wort culture. One portion was placed in the moist chamber at 28° C. and the other in a dry cupboard at 16° C., the crumb being kept moist by the addition of sterilised water. The portion at the higher temperature became ropy in 24 hours, while that at 16° C. showed no signs of the disease at the end of 28 days though still quite moist.

Conclusions.—Elevated temperature appears to be absolutely necessary to the development of ropiness in bread. Even when the bacillus is present in large numbers, moisture alone, when the temperature is low, is incapable of causing its appearance.

Effects of Acidity.—In making wort cultures, it was found that the presence of 0.1 per cent. of acetic acid prevented the growth of the organism. Lactic acid has a similar effect. The author of the paper was therefore led to try the effect of the presence of small quantities of acid in the dough. A number of tests were made and the results recorded in which acetic acid in quantities varying from 0.3 to 1.06 lbs. to the sack were used, and large amounts of wort culture added. The general result was that acetic acid in quantities of from 0.3 to 0.7 lb. to the sack inhibited the development of rope. The minimum quantity would appear to be 0.3 lb., while any excess over 0.7 lb. injuriously affected the gluten. The smaller quantity of acetic acid is not prejudicial to the general qualities of the bread. Lactic acid may be employed instead of acetic acid, but the action is somewhat uncertain with quantities below 0.6 lb. per sack.

Resistance of Organism to Heat.—The bacillus of rope or its spores is exceedingly resistant to heat. Thus an active wort culture was immersed in a boiling water bath for 30 minutes on three successive days. Cultures were made from the wort after each boiling, and yielded vigorous growths. The repeatedly boiled culture was then used in the dough of a trial loaf, and baked for 40 minutes. Notwithstanding the severity of this treatment, the organism was still extremely active and rapidly developed ropiness in the bread. The author of the paper draws the conclusion that it is hopeless to recommend the baker to give bread liable to rope an extra long baking in order to prevent the appearance of the disease.

Morphology and Identity of Organism.—The following are the characteristic details of this organism: A short rod with rounded ends, frequently united in pairs, seldom in chains of more than three. It readily forms ovoid spores which almost entirely fill the cell. In length, it is from 1-1.25 μ; in breadth, 0.75μ.

When cultivated in hanging drop, the organism is sluggishly motile, and is surrounded by a translucent capsule.

It *stains* well by Gram, fuchsin and methylene blue. Spore staining very difficult, usually only successful by Müller's method.

The *growth* is best at temperatures between 25-40° C., stagnates at 15° C.

On *agar-agar,* smeary white growth, brownish on looking through the medium, edges of growth irregular.

On *gelatin,* shining, barely visible, filmy growth, very slowly liquefying the medium.

On *wort gelatin,* white crinkled growth, slowly liquefying medium.

On *peptonised wort,* rapid growth, rendering liquid turbid, and forming a slimy gelatinous film on the sides of flask and surface of liquid. The wort acquires a faintly urinous odour.

On *sterilised bread* the bread becomes brownish as if saturated with syrup, and is gradually converted into a moist viscous mass, emitting a strong valerian-like odour.

In *milk, causes* coagulation, and subsequent partial re-solution of clot.

On *potato,* rapid white crinkling growth ensues, which turns brown with age. A peculiar burnt musty odour is observed.

The foregoing characteristics point to the organism as being identical with *Bacillus mesentericus fuscus* (Flügge, Lehmann and Neumann's *Atlas of Bacteriology,* p. 326, Plate 43).

Habitat.—The bacillus is a frequent inhabitant of soils, vegetables, including potato, and doubtless also the cereals.

Infection of Doughs.—The most important question to the practical baker is how his doughs become infected. Methods generally advocated for prevention and cure of rope hold bakers almost entirely to blame for its appearance in the bakery. For example, it has been ascribed to dampness, accumulation of dirt in false bottoms and crevices of troughs, etc. The suggested remedies have consisted of directions for purification and sterilisation of the bakehouse and all its appliances. These have frequently proved totally inadequate.

Flour.—A complete change of flour has in more than one case resulted in the complete disappearance of the disease. The experience was cited of one large firm of bakers who found that this discarding of their old flours and their replacement by flours from another source resulted in an immediate disappearance of the trouble. Baking tests were then made on each brand of flour in the old stock, taken separately, and all but one were found to be perfectly sound. Every blend used into which this flour had entered was found to yield ropy bread. The evidence was conclusive that this flour had been the means of introducing rope into the bakery.

The author of the paper made a series of bacteriological tests with this flour. One gram of the flour was mixed with 100 c.c. of sterile distilled water, and 1 loopful of the mixture added to various culture media. The growths obtained were identical with those previously isolated from ropy bread. Sterilised bread was successfully inoculated by the addition of 1 loopful of the flour mixture, blank check tests remaining unchanged. Repeat cultures of the organism were made in peptone wort, and these in turn, when added to the dough, induced rope in loaves made from sound flour. On making loaves from the suspected flour alone, portions maintained at 26°-30° C. in a moist atmosphere developed rope, while the check portions, preserved at a temperature of 14°-16° C., remained sound for as long as 14 days. These tests show that the bacillus was undoubtedly present in this sample of flour.

Effect of Yeast.—In order to determine whether the yeast played any active part in the development of rope, some loaves were made with this flour and a commercial baking powder. On being tested, rope developed in the same way and at the same rate as in the yeast-made bread, showing that ropiness is independent of the presence of yeast.

Modern Practice.—In modern practice, the author of the paper regards the flour as the only material responsible for the appearance of this disease. Occasionally in the past, the bacillus may have been introduced by the use of potato ferments; but the employment of potatoes is now almost obsolete, and the fact that the rope bacillus is known to commonly exist in potatoes should furnish a strong additional reason for their abandonment in bread-making.

Practical Test for Rope in Flour.—The following test is intended for the use of practical bakers and millers. It is so delicate that a positive result is obtained from 0.02 gram of a ropy flour, while there is no fear that a genuinely sound flour will be condemned by its employment. Ten test tubes (6 in. by 1 in.) are washed, thoroughly boiled in water for 1 hour, rinsed and drained. When drained, they are baked at 232° C. (450° F.) for 3 hours in order to completely sterilise them. [A baker's oven at full bread-making heat sufficiently answers the purpose.] When cool, place in each tube a finger of bread 3 inches by ½ inch by ½ inch, cut from the centre of the same 2-day old loaf. (The average weight of each piece is 5 grams.) Moisten each piece with 5 c.c. of recently boiled distilled water, then plug all tubes with cotton-wool [previously sterilised by baking to a very light brown tint]. Sterilise the tubes and their contents by immersion in boiling water for 1 hour on three successive days. These tubes are conveniently prepared in batches a few days previous to being required.

In order to test a flour, 2 grams are taken from the sample and well mixed with 100 c.c. of distilled water. The beaker containing the mixture is placed in a boiling water bath for 30 minutes, in order to destroy all organisms except spore formers like the rope bacillus, etc.

To seven of the series of ten prepared tubes add successively 1 to 7 c.c. of the boiled flour mixture, leaving the three remaining tubes to serve as checks. Immediately the tubes have been inoculated, the wool plugs are replaced and the whole ten tubes put into an incubator of 28° C. In the bakery, they may be put in a prover, or in a position near the oven where that temperature is attained and where they will be free from dust. The tubes must be examined at the end of 24 hours, both for the appearance of the bread, and for the smell of ropiness. If the rope bacillus is present, the whole of the inoculated tubes will usually show signs of it. Should only a portion of them, it is well before condemning the flour to repeat the test. In any case the check tubes must remain perfectly sound, or the experiment must be rejected. The experiment should be continued for another 24 hours, and the tubes again examined at intervals. If there is no indication of ropiness in 48 hours, the flour may be passed as sound. Beyond that time the development of moulds and other organisms interferes with the success of the test.

Summary.—Ropiness in bread is produced by varieties of *B. Mesentericus* (Flügge), introduced into the dough through the flour, in which it sometimes occurs in large numbers, possibly coming from the bran coatings. Breads containing bran and low grade white flours are most prone to develop ropiness.

The bacillus is a prolific spore former, the spores being capable of resisting high temperatures for prolonged periods.

Once present in the dough, development of the bacillus, after bread has been made, depends partly upon the reaction of the bread and partly upon atmospheric conditions.

Bread is only faintly acid in reaction and always insufficiently so to naturally prevent the development and spread of ropiness, but if the acidity be increased by addition of small quantities of acetic acid to the dough, development can be prevented.

Low temperature and dryness of the bread store tend to suppress development, but the maximum temperature of 18° C. (65° F.) cannot be exceeded without great risk.

When a batch of bread is found to be ropy, all flour in stock should be at once tested, so as to locate the infected stock, and in the meantime fresh supplies of flour from a different source should be laid in.

When the infected batch of flour has been discovered, it should be isolated, so that it can be worked up under those conditions which are most unfavourable to the development of the bacillus, *i.e.*, the doughs being made slightly acid and the bread being quickly cooled and kept at low temperature during storage. Such flour might advantageously be kept until the colder months, when the prospects of development are at a minimum.

During the summer months, the danger of purchasing ropy flour may be entirely obviated by the application of the bread tube test before buying. (*Jour. Soc. Chem. Ind.*, 1906, 350.)

Watkins' experiments would have been more complete had they included investigations as to how far the development of ropiness was affected by the comparative moisture of bread at temperatures slightly higher than the lower limit of activity of the rope bacillus. He has made it perfectly clear that with a temperature below 18° C. the presence of moisture does not cause the development of ropiness. At 20° C., there would probably be a much more rapid development in a moist loaf than in a very dry one. Some measurements of this stimulating effect of moisture would have added to the value of a very valuable paper. Previously published recommendations to the baker to give his bread an extra long baking, in case of his being troubled with rope, were not probably based on any hope thus to kill the rope organism, but rather to make the bread drier, and thus a less favourable medium for the spread of this disease.

There can be little doubt that Watkins has traced the source of many if not most of the cases of ropiness which trouble the baker. But granted that the flour is the channel of introduction; when once the rope bacillus has permeated the troughs and other utensils, the whole of the advocated precautions for cleaning and sterilising these have all the force and necessity which has been attributed to them.

The rope bacillus is a very ready spore-forming bacillus, and a bakery is from its nature and character a place where spores are readily liberated and disseminated through the atmosphere. There are frequently cases of rope which it is almost impossible to explain otherwise than by aerial infection. Such cases are those in which a complete change of flour has not cured the disease, and where one miller's flour is producing ropy bread in one bakery, while the same flour is yielding perfectly sound bread in another. The cleansing and sterilising of a whole bakery is not necessarily therefore a useless proceeding, but may be an absolute necessity, should the entire building become infected with the rope bacillus. These references are made not with the view of discounting the conclusions arrived at by Watkins, but rather with the object of indicating some possible additional sources of infection and the precautions to be in those cases taken.

The reading of the paper was followed by an interesting discussion, the more important points of which are here given. The chairman, Salamon, drew attention to the strong smell of acetic acid exhibited by a specimen loaf, and inquired as to what would be the effect of traces of nitrogen peroxide on this bacillus in flour, in the manner used for bleaching purposes. Jago asked whether the author had tried using the odourless mineral acids as sulphuric or phosphoric acid, and expressed a doubt as to whether the baker would regard the substitution of sourness for ropiness as an advantage. He pointed out that the presence of dextrinous or gummy bodies in bread, caused it to become ropy much more readily than did the drier types of bread. Hooper insisted on the necessity of flour being kept dry and not allowed to get damp, remarking that many possibly mischievous organisms were more widely spread than was commonly supposed, and were held in check by avoiding the conditions necessary for their development. Humphries found that the addition of 0.25 per cent. of lactic acid was quite sufficient absolutely to spoil bread for commercial purposes. Briant found ropiness to be generally associated with excessive moisture in bread, and also regarded the addition of acid as causing bread to become chaffy in character. Rideal recommended the use of bisulphite of soda in the place of free acids for the inhibition of ropiness. Several other speakers dealt with the question of the identity of the organism. Watkins briefly replied on the whole discussion. He did not regard bleaching as having a sterilising effect on flour, since one of the flours which yielded ropy bread had as a matter of fact been bleached. Mineral acids should not, he thought, be used in an article of diet. Calculation showed that 0.3 lb. of acetic acid to the sack only increased the percentage of acid by 0.0708 per cent., and that quantity did not interfere with the production of a good sweet loaf. (*Jour. Soc. Chem. Ind.*, 1906, 350).

FAULTS IN BREAD.

501. Holes in Bread.—Instead of the even sponginess which should characterise the crumb of good bread, one is occasionally confronted with loaves in which large holes occupy considerable spaces in the interior of the loaf. For their occurrence various explanations have been offered, many of which are ingenious, while others are impossible. An interesting object lesson in their production may be gained by taking a basin of strong solution of soap in water, and blowing into it through a glass tube. A mass of bubbles is formed on the surface of the solution, which fills the whole vessel. Let it rest, and watch the gradual disappearance of the bubbles—careful inspection will show in the interior of the mass some of the bubble walls getting thinner and thinner, until at last they collapse, and several small bubbles coalesce to form one of large size. Practically the same thing occurs in dough; if allowed to get over-proved, it will be seen, on being cut, to contain a number of large holes. Good firm moulding will remove the gas from these, and make a piece of homogeneous dough for the loaf, thus remedying one cause of holeyness; for if a loaf containing these large holes be placed in the oven, they will expand there, and thus give still more irregular aeration. The same process of a number of small holes breaking down into one big one may occur during baking in a piece of dough, which, if cut prior to its going into the oven, would show no signs of large holes. Here the cause must be lack of tenacity in the dough which forms the hole-walls, and the cause of such holes must be found in the constituents of the dough. The elasticity of dough at this stage is principally due to the gluten present, and when fermentation has been carried sufficiently far to destroy the tenacity of the gluten, breaking down into holes is a normal result: holeyness, therefore, for this reason may be an accompaniment of over-worked dough. If a series of loaves be made as suggested in paragraph 495, it is very rarely that holes are found in the earlier and under-fermented loaves. Another cause of this irregularity is the insufficient breaking down and mixing of the sponge with the water and flour of the dough. The latter is frequently made from a comparatively soft, weak flour, and if not thoroughly incorporated with the sponge, leaves portions of inferior tenacity which may readily break into holes. The production of holes by dusting flour being folded up in the interior of the loaf during moulding, and then not thoroughly worked in, thus leaving blebs, which expand into holes on baking, is so absolutely a result of carelessness as to need no further reference.

A curious problem about holes is the liability of cottage loaves to this fault. If some of the same dough be made into "cakes" or "Coburg" loaves, while the remainder is made into cottages, the latter are far more likely to contain holes than the former. One cause of this is possibly the inefficient "bashing" down of the tops of the cottages. A more likely reason is, however, the actual shape of the loaf itself. The top, being smaller, acquires a rigid crust before the lower part of the loaf, and therefore forms a sort of protecting cap over the centre. As expansion goes on in the interior during baking, there is a line of comparatively little resistance immediately underneath the top, and greater expansion takes place in this direction. Evidence of this is afforded by the species of risen waist one sometimes sees in a cottage loaf, consisting of what looks like a third or middle piece in the loaf. This development occurs after the rest of the loaf has set; and, as probably the interior dough has also lost much of its elasticity, there is the formation of a large hole rather than even expansion. Of course the occurrence of such holes means a predisposition of the dough to breaking down into irregular aeration.

The causes of holes in bread may be summed up as being—careless moulding, especially of over-proved dough; lack of tenacity and elasticity of the dough itself, due to soft and irregular flours; insufficient mixing of sponge and dough. Cottage loaves are prone to holes because of the physical effect of their shape on expansion during baking.

502. **Protruding Crusts.**—On crusty bread being packed a little too close in the oven, the loaves, on expanding, touch their neighbors, and a soft crust is formed when they are in contact. Occasionally, when the dough is weak and inclined to "run," it may be observed that the loaves definitely grow toward one another, forming a distinct protuberance on the side of each, as though an endeavour was being made on the part of the loaves to effect actual contact. This apparent attraction is due to the mutual cooling effect of the loaves retarding the formation of a rigid crust on the contiguous parts: expansion continues there after the other parts of the loaves are set, and hence the "kissing" growth toward each other.

503. **Crumbliness.**—The crumbling away, instead of cutting cleanly, exhibited by some bread may be due to the use of harsh, dry flours, not sufficiently fermented; or may also be caused by over-working and proof, making the loaf bigger than the gluten of the dough, at the stage of fermentation when baked, is able to stand and still hold the bread well together. A deficiency of dextrin and soluble starch in the bread also contributes to crumbliness.

504. **Dark Line in Cottages.**—At times, on cutting a cottage loaf, a dark line is seen across the contact surface between the top and bottom of the loaf. Generally when this is the case, if the loaf has any soft crust, that too is seen to be discoloured. The bread is under these circumstances frequently either sour, or approaching it. The primary cause of this dark line is the darkening by oxidation of some of the constituents of the flour; this darkening goes on more rapidly in doughs made from low grade flour or which have been overworked. Proof of this darkening of dough is afforded by pressing a piece of dough down into contact with colourless glass, and letting it stand a time. The air-exposed surface rapidly becomes the darker of the two. This darkening has been found

to be the result of the action of an enzyme to which the name of oxydase has been given. In making sample loaves, especially from dark flours, a streakiness is often observed. The proportionately large external surface darkens, and each time the dough is moulded, the dark portion is worked into the interior, and hence the streaky-baked bread. In any loaf which has been allowed to stand there is more or less darkening of the exterior by oxidation—on baking, this colouration is altogether masked by the caramelisation of the crust. But where the two exteriors have been placed together, as in the surface of contact of the two parts of a cottage, the darkening effect of oxidation is preserved, and may be noticed in the baked loaf.

505. Working with Unsound or Very Low Grade Flours.—In the older literature of bread-making it is interesting to read the directions given under this head; when, through a bad harvest, wheat has either not ripened properly, or has after the reaping been badly wetted, great care is necessary in order to make a passable loaf of bread from the flour produced.

In composition the unsound flours have a low percentage of gluten, and that badly matured; while the soluble proteins are high, and in a comparatively active diastatic condition. The starch granules have their walls softened down and often fissured. The moisture is high, so also, owing to the degradation of starch and proteins, is the soluble extract. These flours are found on testing to be weak and unstable. So far as their treatment is concerned, that commences with the wheats rather than with the flours. A wheat harvested damp is not necessarily unsound; these chemical changes are to a great extent an after-consequence of the dampness. Such wheats should immediately on being harvested be kiln dried at a gentle heat of about 38° C. (100° F.), until the moisture present is reduced to 10 per cent. of the whole grain. While the flour produced from the wheat thus treated may be weak, it will be fairly stable and not unsound. The gluten will be higher, and the soluble extract and proteins comparatively low.

Having by preliminary treatment made the best of an unsound flour, it should be used in the *dough,* which should be got into the oven as speedily as possible. Or, the whole of the flour may be worked with a straight dough on a very short system, using yeast in good quantity. A little compressed yeast added at the dough stage will often be found of service by hastening the fermentation. As unsound flours are particularly liable to produce sour bread, special attention should be paid to the suggestions made in paragraph 497 on Sour Bread. Further reference to unsound flours will be found in the paragraphs describing other methods of aerating bread.

The low grade flours of gradual reduction processes are, if from a sound wheat, perfectly sound in themselves; yet they require some care in manipulation, because they contain the active diastatic constituent of the bran, cerealin, in considerable quantity. Where these flours are employed, a sponge should be prepared from a strong flour and the low grade used in the dough, or the low grade flour worked by a short straight dough system.

506. Use of Alum, Copper Sulphate, and Lime.—Alum, the double sulphate of aluminium and potassium, $Al_2K_2(SO_4)_4 24H_2O$, was formerly largely used as an adulterant of bread. This, and the other substances mentioned, behave as retarding agents to diastasis; with unsound flours they prevent or lessen the degradation of the gluten and starch during fermentation, and so cause a loaf made from a bad flour to be larger, less sodden, and whiter, giving it the appearance of bread made from far better flour. So far, and considered from this aspect alone, the action of alum is remedial; it prevents undesirable changes occurring in the flour during fermentation. There is no doubt that by the use of alum, flour, so bad as to render bread-making in the ordinary manner impossible with it, can be converted into eatable loaves; but if necessity arises for recourse to such flours for bread-making, other processes are now known which achieve the same object by methods that are absolutely unobjectionable. The continued use of alum, even in small quantity, is, according to medical evidence, injurious to health: in particular, the alum remaining, as it does, unchanged in the bread, retards the digestive action of the secretions of the mouth and stomach. **As alum is injurious, and as it is used with the object of enabling inferior flour to be substituted for that of good quality, to the prejudice of the consumer, it is rightly considered as an adulterant, and its use made penal.**

Minute quantities of copper sulphate, $CuSO_4$, have also been employed: its action is very similar to that of alum; but **as all copper salts are very poisonous, its use is even more reprehensible than that of the former adulterant.**

Liebig suggested the employment of lime in solution, lime-water, CaH_2O_2, as a means of preventing excessive diastasis during panary fermentation. This substance is quite as effective as alum so far as the effect on diastasis is concerned, but unlike alum it exerts very little retardation on the alcoholic fermentation caused by the yeast. Lime-water is used by some of the Glasgow bakers, who advertise bread containing it as a specialty. The bread made with lime-water is more spongy in texture, pleasant to taste, and quite free from sourness. In the finished bread the lime no longer exists as free alkali, because the carbon dioxide gas generated during fermentation will have completely changed it into calcium carbonate—

$$\underset{\text{Lime.}}{CaH_2O_2} + \underset{\text{Carbon Dioxide.}}{CO_2} = \underset{\text{Calcium Carbonate.}}{CaCO_3} + \underset{\text{Water.}}{H_2O}.$$

Calcium carbonate, which is identical in composition with chalk, has in small quantities no deleterious action when taken into the system, and may very possibly add to the nutritive value by remedying the natural deficiency of wheat in lime salts. See paragraphs, 536-539.

507. Special Methods of Bread-making.—There are certain special processes employed for bread-making which must next be described.

508. "Vienna Bread."—This is the name applied to rolls and other light fancy bread. Vienna bread is made with patent flour and compressed yeast. No potatoes or ferment is used. Instead of water, the bread is sometimes made with milk or a mixture of milk and water. The following recipe is quoted from *The Miller*:—

Proportions.—8 lbs. of flour, 3 quarts of milk and water in equal proportions, 3½ ounces of compressed yeast, and 1 ounce of salt. The warm water is first mixed with the milk, so as to give a temperature of from 80° to 85° F. Sufficient flour is then added to make a weak sponge, not much thicker than a batter. The yeast is crumbled, mixed well in, and the sponge allowed to stand for about 45 minutes. The rest of the flour is next added slowly, together with the salt; the dough is then thoroughly kneaded and set to ferment for 2½ hours. All Hungarian flour may be used throughout, or the finest English milled flour may be substituted therefor. The bread is glazed during baking by the introduction of a jet of steam into the oven.

509. Leavened Bread.—In France and other parts of the continent bread is made from leaven, which consists of a portion of dough held over from the previous baking. The following description is given on the authority of Watt's *Dictionary of Chemistry*. A lump of dough from the preceding batch of bread is preserved; this weighs about 12 lbs., made up of 8 lbs. of flour to 4 lbs. of water, and is the fresh leaven (*levain de chef*). This fresh leaven, after remaining for about 10 hours, is kneaded in with an equal quantity of fresh flour and water, and thus produces the *levain de premiere*; again, this is allowed to stand for some hours (about eight), and is kneaded in with more flour and water. After another interval of 3 hours, 100 lbs. of flour, 52 of water, and about 1/3 lb. of beer yeast are added; this produces the finished leaven (*levain de tout point*). The finished leaven weighs about 200 lbs., and is mixed, after standing 2 hours, with 132 lbs. of flour, 68 lbs. of water, ½ lb. of yeast, and 2 lbs. of salt. The dough thus formed is divided into two moieties; the one is cut into loaves which are kept for a time at a moderate temperature (77° F.) and then baked. The bread thus produced is sour in taste and dark in colour. The remaining half of the dough is kneaded with more flour, water, yeast, and salt and divided into halves; the one quantity is made into loaves, which are allowed to ferment and then baked; the other is subjected again to operation of mixing with more flour, etc., and working as before. The subdivision is repeated three times; the bread improving at each stage, and the finest and whitest loaves being produced in the last batch. In the more important towns this mode of bread-making is now largely supplanted by the use of distillers' yeast, and seems now to have largely given place to methods more nearly allied to Viennese and English processes.

Leaven fermentation is due to the presence in the leaven of certain species of yeast, which grow and multiply in that medium. These induce alcoholic fermentation of the sugar of the flour.

510. Alcohol in Bread, Proof of Presence of.—Pohl determined the quantity of alcohol in bread in the following manner:—A Papin's digester of about 8 litres capacity was fitted to a Liebig condenser. Into this was placed a charge of 2 litres of water and 990 grams of bread cut up into small cubes. On distillation there was obtained about 500 c.c. of distillate, having a strong odour of new bread. The liquid had an acid reaction and required 1.15 c.c. of normal potassium hydroxide solution for neutralisation. The united distillates from four charges of the apparatus amounted to about 2 litres, and represented 4,419 grams of bread. The distillate was saturated with sodium chloride and re-distilled in a flask fitted with a fractionating (Hempel) still-head, until half the volume had come over. The re-distillate was again saturated with sodium chloride and re-distilled until again half its volume had come over. This operation was repeated until a distillate having a volume of 120 c.c. was obtained. This was then saturated with calcium chloride and distilled until 50 c.c. had come over. The specific gravity of this final distillate was 0.9885, and corresponded to 6.66 grams of alcohol in 100 c.c., so that 100 grams of bread contained 0.0753 gram of alcohol. (*Z. angew. Chem.*, 1906, **19**, 668.)

511. Methods of Aerating Bread Other Than by Yeast.—Carbon dioxide is not only produced by alcoholic fermentation, but may also be generated within dough by purely chemical means, or may be mechanically introduced by first effecting its solution in water. The following description applies to aerating agents used for confectionery as well as bread-making purposes.

512. Aerating Agents.—These essentially consist of (1) substances containing carbon dioxide in a loosely combined condition, as in certain carbonates, and (2) of acids or acid-containing bodies which liberate the carbon dioxide from the members of the first group. The following is a description of the more important of these bodies.

Sodium bicarbonate, $NaHCO_3$.—This body evolves carbon dioxide gas on the application of heat alone, thus:—

$$\underset{\text{Sodium Bicarbonate.}}{2NaHCO_3} = \underset{\text{Carbon Dioxide.}}{CO_2} + \underset{\text{Sodium Carbonate.}}{Na_2CO_3} + \underset{\text{Water.}}{H_2O.}$$

The reaction leaves a residue of normal sodium carbonate, which has a very marked and disagreeable alkaline taste. A very slight excess causes a yellowness in flour and an objectionable smell. These qualities are emphasised where there are lumps of the bicarbonate not properly broken down, or when there is imperfect mixing.

On treatment with acids, the bicarbonate evolves double the quantity of carbon dioxide gas:—

$$\underset{\substack{\text{Sodium.}\\\text{Bicarbonate.}}}{NaHCO_3} + \underset{\substack{\text{Hydrochloric}\\\text{Acid.}}}{HCl} = \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{CO_2} + \underset{\substack{\text{Sodium}\\\text{Chloride.}}}{NaCl} + \underset{\text{Water.}}{H_2O.}$$

With the use of hydrochloric acid as in this case the residual body is sodium chloride or common salt. These bodies are at times used in the aeration of whole-meal bread. The salt produced takes the place in whole or in part of that always added for flavouring purposes.

Ammonium carbonate (*"Volatile"*).—Under the name of "Volatile," the commercial ammonium carbonate is also sometimes used as a source of carbon dioxide gas. This body is really a mixture of ammonium carbonate and carbamate, and may be represented by the formula $2(NH_4)_2CO_3.CO_2$, and contains in 100 parts, NH_3, 28.81; CO_2, 55.93; and H_2O, 15.26. On being dissolved in water and heated, the normal carbonate is first formed with the liberation of carbon dioxide, after which the whole of the carbonate completely volatilises, being converted into gaseous ammonia and carbon dioxide:—

$$\underset{\substack{\text{Commercial Ammonium}\\\text{Carbonate.}}}{2(NH_4)_2CO_3.CO_2} = \underset{\substack{\text{Normal Ammonium.}\\\text{Carbonate.}}}{2(NH_4)_2CO_3} + \underset{\text{Carbon Dioxide.}}{CO_2.}$$

$$\underset{\text{Ammonium Carbonate.}}{2(NH_4)_2CO_3} = \underset{\text{Ammonia.}}{4NH_3} + \underset{\text{Water.}}{2H_2O} + \underset{\text{Carbon Dioxide.}}{2CO_2.}$$

On being heated, therefore, the whole of the carbonate is converted into gaseous products.

This residue is therefore entirely gaseous, and consists of carbon dioxide and ammonia. Until the latter gas leaves the goods in which "volatile" has been used, they have the disagreeable odour and flavour of ammonia. This substance is mostly used for aerating small porous articles which readily permit its escape. It is obviously not suited for the aeration of bread.

Tartaric Acid, $H_2C_4H_4O_6$.—This acid, of which a description has already been given, is very soluble in water, hot or cold, and acts immediately on sodium bicarbonate in the cold, liberating carbon dioxide:—

$$\underset{\substack{\text{Tartaric}\\\text{Acid.}}}{H_2C_4H_4O_6} + \underset{\substack{\text{Sodium}\\\text{Bicarbonate.}}}{2NaHCO_3} = \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{2CO_2} + \underset{\substack{\text{Sodium}\\\text{Tartrate.}}}{Na_2C_4H_4O_6} + \underset{\text{Water.}}{2H_2O.}$$

The residual body is sodium tartrate; it is soluble and has a bland and faintly saline taste, which is practically imperceptible in the baked goods. Commercial tartaric acid may now be obtained almost chemically pure.

Cream of Tartar, $KHC_4H_4O_6$.—This body, known also as hydrogen potassium tartrate, is tartaric acid with half its acid properties neutralised by combination with potassium. Consequently it has only half the strength of tartaric acid. Cream of tartar differs remarkably from tartaric acid in that it is only very slightly soluble in cold water, whereas it is readily soluble in hot water. The result of this is that when cream of tartar is used with sodium bicarbonate very little action goes on in the cold. But when the goods get hot in the oven a very rapid and energetic evolution of gas occurs just at the time when it is wanted. For this reason cream of tartar is an exceedingly useful body to the baker and confectioner. Its chemical action is shown by the following equation:—

$$\underset{\substack{\text{Cream of}\\\text{Tartar.}}}{\mathrm{KHC_4H_4O_6}} + \underset{\substack{\text{Sodium}\\\text{Bicarbonate.}}}{\mathrm{NaHCO_3}} = \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{\mathrm{CO_2}} + \underset{\substack{\text{Potassium}\\\text{Sodium Tartrate.}}}{\mathrm{KNaC_4H_4O_6}} + \underset{\text{Water.}}{\mathrm{H_2O}}.$$

The residual body is potassium sodium tartrate, known commercially as "Rochelle Salts," which like sodium tartrate is possessed of very little taste. Both sodium tartrate and Rochelle salts are aperient bodies, the latter being the active ingredient in the well-known Seidlitz powders. For the same amount of gas evolved, cream of tartar leaves double the residue in the goods that is left with tartaric acid. Commercial cream of tartar differs very much in its degree of purity. It can, however, be bought with a guarantee of containing 98 per cent. of the pure substance; and this no doubt is the best form in which to buy the salt for aerating purposes.

Acid Calcium Phosphate, $\mathrm{CaH_4(PO_4)_2}$.—This salt is used to a considerable extent for aerating purposes. It is soluble in cold water, and therefore behaves somewhat similarly to tartaric acid. In view of the fact that there is a number of possible phosphates, several reactions may occur between this body and sodium bicarbonate. The following are among the most important:—

$$\underset{\substack{\text{Acid Calcium}\\\text{Phosphate.}}}{\mathrm{CaH_4(PO_4)_2}} + \underset{\substack{\text{Sodium}\\\text{Bicarbonate.}}}{\mathrm{NaHCO_3}} = \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{\mathrm{CO_2}} + \underset{\substack{\text{Calcium Sodium}\\\text{Trihydrogen Phosphate.}}}{\mathrm{CaNaH_3(PO_4)_2}} + \underset{\text{Water.}}{\mathrm{H_2O}}.$$

$$\underset{\substack{\text{Acid Calcium}\\\text{Phosphate.}}}{\mathrm{CaH_4(PO_4)_2}} + \underset{\substack{\text{Sodium}\\\text{Bicarbonate.}}}{\mathrm{2NaHCO_3}} = \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{\mathrm{2CO_2}} + \underset{\substack{\text{Calcium Di-sodium}\\\text{Di-hydrogen Phosphate.}}}{\mathrm{CaNa_2H_2(PO_4)_2}} + \underset{\text{Water.}}{\mathrm{2H_2O}}.$$

In the former of the above equations, one molecule of acid calcium phosphate has reacted with one molecule of bicarbonate, and has liberated one molecule of carbon dioxide. Mixed in these proportions the resultant phosphate is acid to litmus and to the taste. In the case of the second equation, one molecule of the acid phosphate has reacted with two molecules of bicarbonate, and has liberated two molecules of carbon dioxide. The resultant body still contains acid hydrogen, but is neutral to litmus and also phenolphthalein: also it is neither acid nor alkaline to the taste but only just saline in flavour. These are the correct proportions for use as an aerating mixture, and correspond to 13.9 parts of the pure acid salt to 10 parts of bicarbonate. As to how much of the commercial salt must be used will depend on its degree of purity, which varies greatly, as will be seen from the following table of analyses of samples which have recently passed through the hands of the author:—

	I.	II.	III.	IV.
True acid phosphate	11.23	34.39	69.50	74.18
Neutral phosphate, etc. ..	31.18	19.80	28.73	23.64
Matter insoluble in hydrochloric acid	Trace	0.90	0.26	0.84
Calcium sulphate	57.59	44.91	1.51	1.34
Totals	100.00	100.00	100.00	100.00

Numbers I. and II. are practically valueless, besides which their use would render the person so doing liable to a prosecution for adulteration with calcium sulphate. Numbers III. and IV. are very good samples, and taking their mean as 71.84 it is easy to calculate how much of the commercial salt must be taken to equal 13.9 parts of the pure body.

As 71.84 : 13.9 :: 100 : 19.3 parts of the commercial phosphate required.

The rule of double quantity of phosphate to bicarbonate is therefore a safe one for good samples but would have to be exceeded for those of low quality.

A higher degree of purity than that of No. IV. is scarcely desirable, since the pure salt is somewhat deliquescent.

Much of the acid calcium phosphate on the market is exceedingly impure, some samples containing as much as 50 per cent. of calcium sulphate. It can, however, be bought from the best makers with a guarantee of 98 per cent. pure phosphate salts. Numbers III. and IV. in the preceding table are in practical conformity with this standard.

Acid Potassium Phosphate, KH_2PO_4.—The potassium salt has been, and still is at times, employed instead of that of calcium. The reaction between it and sodium bicarbonate is as follows:—

$$\underset{\substack{\text{Acid Potassium}\\\text{Phosphate.}}}{KH_2PO_4} + \underset{\substack{\text{Sodium}\\\text{Bicarbonate.}}}{NaHCO_3} = \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{CO_2} + \underset{\substack{\text{Potassium Sodium}\\\text{Hydrogen Phosphate.}}}{KNaHPO_4} + \underset{\text{Water.}}{H_2O}.$$

There seems to be no advantage in having a residue of potassium phosphate rather than calcium phosphate in the goods, provided that the calcium phosphate used is commercially pure. Further, potassium salts are now exceedingly expensive.

Acid Potassium Sulphate, $KHSO_4$.—This salt is soluble in cold water and acts similarly to tartaric acid when used as an aerating agent. It is much the cheaper of the two and produces the following changes with sodium bicarbonate:—

$$\underset{\substack{\text{Acid Potassium}\\\text{Sulphate.}}}{KHSO_4} + \underset{\substack{\text{Sodium}\\\text{Bicarbonate.}}}{NaHCO_3} = \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{CO_2} + \underset{\substack{\text{Potassium Sodium}\\\text{Sulphate.}}}{KNaSO_4} + \underset{\text{Water.}}{H_2O}.$$

The residual potassium sodium sulphate is a comparatively tasteless body with aperient properties.

"Cream Substitutes."—These substances are lower in price than cream of tartar, and mostly consist of acid phosphates or sulphates, or mixtures of the two. The acid strength is let down to that of cream of tartar by the addition of starch, usually in the form of rice or cornflour. Strictly, these bodies are not substitutes for cream of tartar as they do not possess the same property of insolubility in cold water, and ready solubility in hot water. By careful selection and admixture, their rate of cold water solubility is considerably slowed down, and within limits they can be used instead of cream of tartar. Their true analogue is not, however, cream of tartar, but rather tartaric acid.

Alum, $Al_2K_2(SO_4)_4, 24H_2O$.—The alums liberate carbon dioxide from sodium bicarbonate according to the following equation:—

$$\underset{\text{Potash Alum.}}{Al_2K_2\,(SO_4)_4{,}24HO_2} + \underset{\text{Sodium Bicarbonate.}}{6NaHCO_3} = \underset{\text{Carbon Dioxide.}}{6CO_2} + \underset{\text{Aluminium Hydroxide.}}{Al_2(HO)_6} +$$

$$\underset{\substack{\text{Potassium}\\\text{Sulphate.}}}{K_2SO_4} + \underset{\substack{\text{Sodium}\\\text{Sulphate.}}}{3Na_2SO_4} + \underset{\text{Water.}}{24H_2O}.$$

The employment of alum in the preparation of food is regarded as an adulteration.

Equivalent Weights.—The following table gives the weight of each substance required by 10 parts by weight of sodium bicarbonate:—

Name.	Weight.
Tartaric Acid	8.93
Cream of Tartar	22.38
Acid Calcium Phosphate, pure,	13.90
Acid Calcium Phosphate, commercial,	about 20.00 to 22.50
Acid Potassium Sulphate	16.19

Comparative Evolution of Gas.—The comparative volume of gas, measured at 100° C., evolved by one part by weight (1 gram) of various aerating mixtures, is given in cubic centimetres in the following table:—

NAME OF AERATING AGENT.	
Ammonium carbonate (volatile), on being heated yields—ammonia gas, 516; carbon dioxide gas, 387	903
Sodium bicarbonate by action of heat alone	181
Mixture in proportion of 10 parts sodium bicarbonate to 8.93 parts tartaric acid	191
Mixture in proportion of 10 parts sodium bicarbonate to 22.38 parts cream of tartar	112
Mixture in proportion of 10 parts sodium bicarbonate to 22.5 parts acid calcium phosphate	112

In summing up the general behaviour of these, and deciding as to their suitability for aerating purposes, the first consideration is whether rapidity of action is objectionable or otherwise. If the goods can be baked at once before the action of the acid and soda on each other is over. then tartaric acid and soda answer well. But it must be remembered that this action commences *immediately* the ingredients are wetted. On the other hand, if it be desired that no action shall occur before the goods are heated in the oven, then cream of tartar and soda are preferable, as this mixture remains quiescent until the temperature is raised. Where immediate action is no detriment, acid and soda are indicated, and this mixture possesses the advantage of leaving only about half the residue left by cream of tartar and soda. Ammonium carbonate has also a deferred action, but there is the unpleasant ammoniacal odour left in the hot baked goods. Provided this is allowed to escape, and the goods are odourless, then no residue whatever remains in them.

513. Baking Powders.—These consist of bicarbonate of soda put up with one or more of the acid bodies previously described. Baking powders are used more extensively in America than in England for bread-making purposes, and their composition has been made the subject of investigation by one of the State departments. They are classified according to the nature of the acid constituent they contain into three groups, Tartrate, Phosphate, and Alum powders.

In the manufacture of baking powders, the acid ingredient, together with the proportionate quantity of bicarbonate of soda, is mixed with air-dried starch. This latter component increases the weight of the baking powder; it also, owing to the hygroscopic nature of starch, helps to keep the active ingredients free from moisture.

514. Self-Raising Flour.—The articles sold under this name consist of flour, mixed with acid tartrates or phosphates, and the bicarbonate of soda: as with baking powder, the addition of water causes the evolution of gas. Self-raising flours may be viewed as being flours sold with baking powder already mixed with them. It is claimed for the use of phosphates in this manner that it replaces these important salts which are removed from the wheat in the bran.

515. Use of Hydrochloric Acid.—In the manufacture of wholemeal bread the method is sometimes adopted of employing hydrochloric acid and sodium carbonate in the exact proportions in which they neutralise each other: they then not only evolve carbon dioxide gas, but also yield sodium chloride, or common salt, thus:—

$$\underset{\text{Sodium Bicarbonate.}}{NaHCO_3} + \underset{\text{Hydrochloric Acid.}}{HCl} = \underset{\text{Sodium Chloride.}}{NaCl} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

The salt thus formed lessens the quantity which otherwise would have to be added to the bread. Great care is requisite in the proper mixing of the acid and the carbonate with the meal: it is also important that exactly the right proportions should be taken. A rough measurement of the strength of the acid may be made by taking a weighed quantity, say an ounce, of the bicarbonate of soda, dissolving it in boiling water in a beaker, and then adding a few drops of methyl orange solution. The hydrochloric acid should be measured, or else a quantity placed in a beaker, and weighed in it; then add the acid little by little until one drop changes the colour of the bicarbonate of soda solution from yellow to red. Then again weigh the acid containing beaker; the loss in weight gives the quantity of the hydrochloric acid, equivalent to an ounce of the bicarbonate. Commercial hydrochloric acid is usually sold with a guaranteed density of 1.15; this is equivalent to about 30 per cent. of the anhydrous acid. As 84 parts of sodium bicarbonate are exactly neutralised by 36.5 of anhydrous hydrochloric acid, and as this amount is contained in 122 parts of the commercial acid, the bicarbonate of soda and hydrochloric acid of this density should be used in the proportions of 84 of the bicarbonate to 122 of the acid, or practically in the proportions of 2 to 3 by weight. It has been recommended that 3 lbs. each of the acid and bicarbonate be used to the sack of flour: these proportions leave, however, a considerable excess of the carbonate in the bread. The great objection to the hydrochloric acid method is that the commercial acid frequently contains traces of arsenic, and thus a minute quantity finds its way into the loaf.

516. Whole-Meal Bread.—It is principally in making whole-meal bread that the hydrochloric acid and bicarbonate method is employed. The reason is that, with the presence of the bran, cerealin is introduced into the dough in such quantity that, if ordinary fermentation processes be employed, diastasis proceeds to a very serious extent. The excess of dextrin thus produced causes the dough to become soft and clammy, and so to offer a matrix in which sour and other unhealthy fermentations are apt to proceed rapidly. The brown colour is due to the excess of dextrinous matter contained in the bread. The rapidity of the acid treatment enables the bread to be got into the oven before diastatic action can have proceeded to any extent. When the fermentation method is employed for making whole-meal bread, it is customary to make a sponge with a small quantity of very strong flour, and only add the whole meal at the dough stage. However made, whole-meal bread has a great tendency to become sodden: in order to drive off excess of moisture it has to be baked for a considerable time, consequently the loaf has often a very thick crust, while the interior is still unduly moist. In summer time particularly the making of whole-meal bread is an unsatisfactory operation, as great difficulty is often experienced in producing a sound and well-risen loaf.

In all the operations just described, carbon dioxide is formed in dough, and thus raises it. The chemical action which under these circumstances takes place is not, however, a complete representative of that which occurs with yeast. One of the functions of this body during the fermentation of bread is to act on the protein, and also to a certain extent on the starch; the result of such action, when normal, is to impart to the bread a characteristic flavour that can be obtained by no other means at present known.

517. The Aeration Process.—One other method of aerating bread remains for consideration, and that is the system associated with the name of Dr. Dauglish. The carbon dioxide is in this method propared apart from the bread and forced into water under pressure; this water, which is akin to the aerated water sold as a beverage, is then used for converting the flour into dough, the whole operation of kneading being performed in a specially prepared vessel in which the pressure is maintained. The kneading being completed, the dough is allowed to emerge from the kneading vessel, and immediately rises, from the expansion within it of the dissolved carbon dioxide. Such was the nature of the method originally employed by Dauglish; but now the following modification is used:—A weak wort is made by mashing malt and flour; this is allowed to ferment until through the agency of *bacteria* it has become sour, in all likelihood through the presence of lactic acid. The water to be aerated is first mixed with a portion of this weak acid liquid: it is then found to absorb the carbon dioxide gas much more readily. The acid also softens the gluten. So far as the actual aeration process is concerned, this method is mechanical rather than chemical. The great objection is that those more subtle changes by which flavour is produced do not occur here more than in the other purely chemical methods of bread-making before described. A common experience in eating aerated bread for some time is that it after a while gives the impression of rawness. This is doubtless due to there being no such enzymic action on the proteins as results from fermentation. It is partly to meet this want that the fermented wort is now added as a part of the process. On the other hand, as a compensation for this lack of flavour-producing changes, the operation is one in which there is no danger of those injurious actions occurring of which much has already been said. Working with flours that are weak and damp, or even bordering on the verge of unsoundness, it is still possible to produce a loaf that should be wholesome and palatable, certainly superior to many sodden and sour loaves made from low quality flours fermented in the ordinary manner. In thus stating that it is possible to treat flours of inferior quality by this aerating method, the authors wish specially to carefully avoid giving the impression that it is the habit of those companies which work Dauglish's method to make use of only the lower qualities of flour; they have never had any reason whatever for supposing such to be the case. Their object in the present remarks is simply to point out the advantages possessed by this method, should circumstances unfortunately arise rendering it necessary to have recourse to inferior flours for bread-making purposes.

Richardson claims for the aeration process that it is eminently suited for the manufacture of whole-meal bread. Of this there is not the slightest doubt: whole-meal is not well fitted for fermentation methods, and the aeration process distends the dough with gas, without the addition of any foreign substance whatever.

It is also claimed for the aeration process that it enables the cerealin to be retained within the bread; and that this is "a most powerful agent in promoting the easy and healthy digestion of food." It is stated that this agent is retained uninjured by the aerated bread process. The author of this statement apparently overlooks the fact that diastatic action is destroyed by the subjection of proteins to a temperature approaching 212°F. However active, therefore, cerealin may be in effecting diastasis of starch during panary fermentation, its power is destroyed by efficient baking, and the bread contains no active diastatic principle. This remark applies with equal force to bread containing malt; it is so well known that malt infusion converts starch into dextrin and maltose, that from time to time it has been introduced into bread. It must here, too, be remembered that the baking entirely destroys its diastatic action, and so causes the malt to be inert as a digestive substance.

518. **Gluten Bread.**—It is important that the diet of diabetic patients should contain no sugar, starch, or other compounds capable of being converted into sugar. For their use bread is prepared containing the gluten only of the flour. A strong flour should be selected and made into a stiff dough with water only; this is allowed to stand for almost an hour, and then carefully kneaded in small pieces at a time in a vessel of water; the starch escapes and the gluten remains behind. Care is necessary in prforming this operation, as otherwise the lump of dough does not hold together. Should there be any difficulty, the dough may be enclosed in muslin prior to being kneaded. The gluten must be washed in successive waters until it no longer contains starch; at this point the gluten ceases to render the washing water milky. When properly washed the gluten is ready for the oven, and is usually baked in small rolls or buns. As it swells enormously during baking, a very small piece is sufficient for each roll.

519. **Rye Bread.**—On the European Continent, bread is made to a considerable extent from rye. The following are the results of analyses of samples of two such breads:—

	Pumpernickel. Black Bread.	Vienna Rye Bread.
Proteins	8.90	8.30
Starch, etc.	39.74	55.14
Sugar	3.28	1.46
Fat	2.09	0.33
Cellulose	1.79	0.97
Mineral matters	1.29	1.90
Water	42.90	31.91

Pumpernickel is the well-known black bread of Northern Germany. The Vienna sample is of a whiter type, containing considerably less of the bran.

520. **Unsuitability of Barley Meal, etc., for Bread-making.**—Questions often arise as to why barley and other cereals do not make such good bread as does wheaten flour. One reason has already been given: wheat is distinguished from the other somewhat similar foodstuffs by its containing gluten; it is the presence of this peculiar albuminous body that confers on wheat flour its characteristic bread-making qualities. The proteins of the other cereals, and also of peas and the other leguminous seeds, possess more active diastatic properties—consequently during fermentation they yield much dextrin, and produce dark coloured, sodden, and often sour breads. The diastase of rye is particularly active. In addition to the colour produced by diastasis, peas have naturally a dark colour of their own, so that their introduction into bread would very materially affect the colour. In comparing barley and rye flours against that of wheat, the differences in the respective milling processes must not be ignored. The bran and germ of wheat are separated from the flour by most refined methods, while barley and rye are ground, and the meal purified, by the crudest appliances. This must of necessity make a difference in the character of the flour.

521. Wheat and Flour Blending.—The consideration of the whole problem of blending flours and wheats has been purposely postponed until this stage, in order that the reader may have before him an account of the various changes which flour undergoes during the operations of panary fermentation. These changes, in short, consist in more or less conversion of starch into dextrin and maltose, and in the gradual softening and otherwise altering the gluten of the flour. As has been previously insisted on, the gluten must have had during fermentation sufficient opportunity to hydrate and soften sufficiently; but must not have been allowed to further change, as if so it will have lost its tenacity, and will produce an inferior loaf. A great deal of the success of a skilled baker depends on his having acquired the experience which enables him to take his dough and place it in the oven just at this right point when fermentation has proceeded sufficiently far to get the gluten of the flour in its best possible condition.

The problem is further complicated by the fact that different flours require, in order to arrive at this stage of maturity, different lengths of time in fermentation; hence, as already explained, flours from hard wheats are commonly used in the sponge, while those from soft wheats are employed in the dough. There can be no doubt whatever that by this arrangement far better bread is produced than if the flours be used in the reverse order. It is, then, perfectly safe to state that **the length of time flours require to stand in fermentation is in proportion to their hardness or stability.** This being the case, the question arises as to how this end may best be secured.

Probably the most keenly contested question on this whole problem of blending is whether it shall be done by the miller or the baker. Of prior importance, however, to this matter of by whom the blending shall be performed is that of the baker's actual requirements in flour. Evidently the baker who works either with a ferment and dough, or an off-hand dough, needs but one flour for each quality of bread, and may therefore either buy a flour which suits his requirements, ready mixed by the miller, or may purchase individual flours and mix them together. With the increased adoption of straight dough systems, there is naturally a larger demand for ready blended flours. But even those who employ this method may often find a blend of their own more suited to their particular requirements than a single miller's flour. On the other hand, the baker who employs the sponge and dough system will, in the great majority of cases, find it advantageous to use flours of a different class for his sponges and doughs respectively. As already explained, for the former he almost invariably selects a hard, strong flour, which is best made from either Spring American or the harder Russian wheats. For some methods of working, an admixture of a small proportion of softer flour is an improvement, as the proteins of the latter exercise a distinct mellowing and ripening effect on the glutens of the hard flours.

For doughing purposes the wheat or flour mixture is more varied; thus the soft, sweet, "coloury" flours are used at this stage; so also is usually a certain proportion of hard flour, which, if not too much, is sufficiently softened by the diastatic action of the softer flours by which it is accompanied.

There is always a demand by the more advanced bakers for flours milled from single wheats, a demand evidently based on the greater individuality which such flours naturally possess. Among these are hard Spring Americans, which can be differentiated into Manitoban wheat flours, Northern Minnesota flours, and Southern Minnesota flours, all of which have their special characteristics. Prime hard Russian wheat flours would also find a market were they obtainable. Winter American flours, both from soft wheats and also the hard Kansas wheats, may also be included in this group. So, too, may best English wheat flours, and also those from Hungarian wheats.

The following are among the advantages which accrue to the baker by working on the principle of blending flours:—

(1) There are frequently offering parcels of flour which possess in a marked degree some one quality, but are deficient in others. Because they cannot well be used alone, they may be purchased at a lower figure. and the blender, by mixing, can utilise such flour to advantage. In other words, given the requisite knowledge, it is often cheaper to prepare the quality and character of flour required for use from a mixture of different qualities obtainable on the market, than to buy the actually wanted quality mixed ready for use.

(2) The baker who blends flours has a greater control over the quality and character of the flour he uses in his work. Thus, he can readily either improve or diminish the value of his sponging flours by the addition of a bag or a sack of a better or worse flour: so, too, colour, flavour, and other characteristics of his flours can be readily modified at will, and much more effectively than if he simply obtains one ready-made flour from the miller. He can similarly modify a flour used for straight doughs.

(3) The baker can introduce each particular variety of flour at that stage of fermentation which best suits its particular characteristics.

Blending affords greater chances of successful work with flour, but at the same time entails greater risks, because accurate knowledge of the properties and the characters of the various flours blended is requisite, and also of their effect on each other when blended.

The baker who blends should lay himself out to select flours for their predominant quality; for example, one brand for strength, another for colour, another for flavour, and so on. By appropriate means he will judge the exact character of each of these flours in the separate state, and then can readily, with a little care, prepare whatever blends best suit his work. The modern baker will have no difficulty in finding his requirements in this direction met by the modern miller.

Millers, in blending, usually first mix their wheats, and let them lie a time before sending to the rolls—if hard and soft wheats are thus blended, each exerts a favourable influence on the other in the way of rendering it more amenable to milling. Thus, a very hard wheat, and also a very soft one, are each more difficult to mill successfully than a mixture of intermediate character; and consequently a miller's argument is this—if the two flours are to be mixed after being milled, why not have the wheats first mixed, as the resultant flour is of better quality, everything else being equal, than if the two separate flours are mixed after milling? On the other hand, certain millers have distinct and separate plants, the one for hard wheats and the other for soft, and mill and treat each separately, afterwards mixing the flours. The evidence, therefore, of even millers themselves is undecided on this point of blending before or after milling.

Whether blending be done by the miller or the baker, an undoubted advantage arises from the latter having a clear idea of his exact requiremnts in flour, and how they may best be met. With clear and full knowledge on these points, whether the baker blends himself or gets that service performed for him by the miller, the result is the more economic production of a better and higher class loaf.

522. Changes in Flour Resulting from Fermentation.—A series of experiments has been made by the authors with the following objects:—

I. Determination of the amount of gas evolved during fermentation under the described conditions.

II. Investigation of the changes produced by fermentation in the composition of the flour.

III. Effect produced by the addition of various substances to the flour on the quantity of gas evolved, and on the changes therein resulting from fermentation.

Outline of Experimental Method.—In each test, 200 grams of flour were taken, and 100 grams of water at 30° C.; these with 2 grams of salt, and 4 grams of fresh distillers' compressed yeast formed the basis of the dough. Various additions were made as subsequently described. The doughs were carefully mixed with a spatula in a basin, and finally made by hand, but with as little handling as possible. They were then transferred to a weighed enamelled steel beaker and the weight ascertained. Waste and loss in making were thus determined. A small portion of the dough was then taken for estimation of water and solids. The remainder was carefully weighed, and the beaker, *a*, at once inserted in the fermenting apparatus. This consisted of a gun-metal vessel, *b*, Fig. 33, fitted with a glass lid, *c*, and an outlet tubulure, *d*. The vessel, *b*, was fixed in a water bath, *e*, maintained at a constant temperature by means of an automatic gas regulator, *f*. The tubulure, *d*, was connected with a gas measuring apparatus, *g*, similar to that described in par. 364. The joint between *b* and *c* was made with rubber solution, and the two fastened together by means of four screw clamps, *h*, applied round the edges. The doughs when made had a temperature of 26° C., and the water bath was kept at that temperature throughout the whole series of experiments. The volume of gas evolved was read off at intervals, usually of one hour, and the readings continued for 6 hours, with the exception of No. IV., in

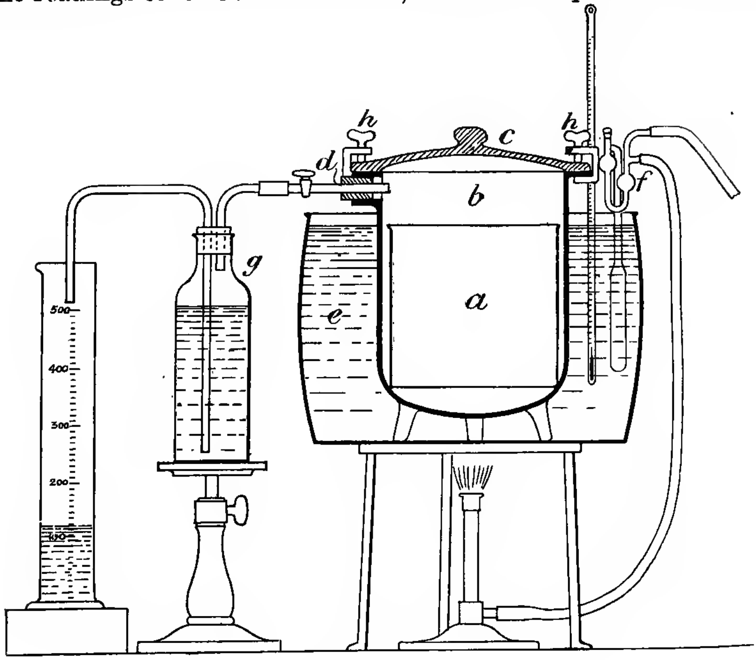

FIG. 33.—Fermenting Apparatus.

which they were taken for 20 hours. The beaker of fermented dough was then removed from the apparatus and weighed. An analysis was subsequently made on the fermented dough.

The following table gives the numbers of the experiments, and the substances used in each. As already mentioned, the four principal ingredients were always taken in the same proportions, viz., flour, 200 grams; water, 100 grams; salt, 2 grams; and yeast, 4 grams. The yeast throughout was the same brand, and that employed was selected each day from the centre of a fresh and previously unopened bag.

No. I. Flour, water, salt, *no yeast.*
,, II. Flour, water, salt, malt flour 1 gram, *no yeast.*
,, III. Flour, water, salt, yeast.
,, IV. Flour, water, salt, yeast (2nd experiment).
,, V. Flour, water, salt, yeast, sugar 2 grams.
,, VI. Flour, water, salt, yeast, starch 2 grams, gelatinised in portion of the water.
,, VII. Flour, water, salt, yeast, malt flour 1 gram.
,, VIII. Flour, water, salt, yeast, starch 2 grams, gelatinised in portion of the water, malt flour 1 gram.

GAS EVOLVED.

No evolution of gas occurred in Nos. I. and II.

Time.	No. III.	No. IV.	No. V.	No. VI.	No. VII.	No. VIII.
0	0	0	0	0	0	0
	245	350	170	256	343	187
1 hour	245	350	170	256	343	187
	365	384	240	316	440	293
2 hours	610	734	410	572	783	480
	440	416	360	490	536	342
3 “	1,050	1,150	770	1,062	1,319	822
	330	209	380	400	475	360
4 “	1,380	1,359	1,150	1,462	1,794	1,182
	165	198	340	185	258	344
5 “	1,545	1,557	1,490	1,647	2,052	1,526
	125	104	330	180	268	310
6 “	1,670	1,661	1,820	1,827	2,320	1,836
		96				
7 “		1,757				
		92				
8 “		1,849				
		176				
10 “		2,025				
		156				
12 “		2,181				
		109				
14 “		2,290				
		109				
16 “		2,399				
		106				
18 “		2,505				
		104				
20 “		2,609				

Numbers I. and II. were made up in order to make subsequent tests on the doughs after standing. As would be expected, there was no evolution of gas in either case. No. III. may be compared with a somewhat similar experiment described in paragraph 436. There the conditions were as nearly as possible those of actual practice: it may be taken therefore that the fermentation in this latter case was more than double that which occurs in normal bread-making, being represented by 1,670 c.c. as against 705 c.c. of gas. Nos. III. and IV. are duplicates for the first 6 hours, but in IV., gas was evolved much more vigorously at the start, a result which must be regarded as due to greater initial fermentative power in fresh yeast of another day's supply. At the end of 6 hours the quantity evolved was practically alike in both cases, 1,670 as against 1,661 c.c. But right up to the close of No. IV. there was a considerable and steady evolution of gas. Nos. V. and VI., respectively containing added sugar and gelatinised starch, gave about the same amount of gas, 1,820 and 1,827 c.c., the maximum production of gas being greater, however, in No. VI. In No. VII., to which malt flour had been added, there was considerably more gas than in any of the other tests, 2,320 c.c. This amount is equivalent to that evolved in No. IV. in about 14½ hours. In No. VIII., which contained both malt flour and gelatinised starch, the gas evolved was only about the same as gelatinised starch only, 1,836 as against 1,827 c.c.

Analyses of Flour and Dough.—In the flour, the gluten was determined in the usual manner, and dried. The true gluten was estimated by the Kjeldahl process on the dry gluten. The gliadin is that yielded by direct extraction of the wet gluten from 10 grams of flour, being 2.8 grams. A measured quantity of 100 c.c. of 70 per cent. alcohol was employed. The wet gluten and 20 grams of washed and dried precipitated chalk were placed in a mortar and triturated with a sufficiency of the alcohol to produce a slack dough. The trituration was continued until the whole of the gluten was disintegrated, no visible particles being present. This dough, together with the remainder of the alcohol, was transferred to a flask and vigorously shaken. In every case the sediment was carefully examined in order to see that all the gluten had been thoroughly comminuted. The contents of the flask were then raised to the boiling point, and again thoroughly shaken. The flask was then allowed to stand over night, shaken up once more in the morning, allowed to settle for a few minutes, and filtered. A direct estimation by weight was then made by evaporating 50 c.c. of the filtrate and drying off in a tared glass dish. True gluten, less gliadin, was then reckoned as glutenin. The soluble extract was obtained by the addition of 500 c.c. of distilled water to 50 grams of the flour, shaking vigorously at intervals during 30 minutes in the cold and then filtering after 5 minutes' subsidence. A sufficient quantity of a turbid filtrate was almost immediately obtained, and this was filtered bright on a separate filter. Aliquot parts of this solution were taken for the estimation of reducing and non-reducing sugars and soluble proteins.

The doughs were first thoroughly mixed and re-kneaded; 50 grams were then taken, and washed in successive small quantities of tap water (deep well from the chalk), with separation of gluten. As 50 grams of dough contain about 21 grams of starch, having a specific gravity of 1.5, the starch present was assumed to occupy 14 c.c. The washing water was therefore made up to 514 c.c., allowing 500 c.c. of liquid. To this solution, 10 grams of thoroughly washed and dried kieselguhr were then added, and the solution filtered bright. Total soluble matters, sugars, and protein, were then determined in the filtrate. The gluten was weighed in the wet and dry states, and true gluten and gliadin and glutenin estimated as before. The moisture was determined direct on a portion of the dough, and the acidity on another portion direct. The dough was triturated with distilled water in a mortar and titrated with phenolphthalein and $N/10$ soda, the acidity being calculated as lactic acid.

The results of the analyses are given in the following table, both on the flour and dough as examined and as calculated on the water-free solids. The numbers attached to the doughs are the same as before; the flour is designated No. O.

COMPOSITION OF FLOUR AND DOUGHS.

	No. 0.		No. I.		No. II.	
Constituents.	As Exd.	Water Free.	As Exd.	Water Free.	As Exd.	Water Free.
Moisture	14.27	—	42.11	—	41.99	—
Gluten, Wet	28.05	32.72	20.40	35.29	20.70	35.40
„ Dry	10.50	12.14	6.34	10.97	6.50	11.11
„ True	8.87	10.33	5.31	9.19	5.84	9.99
Gliadin ex gluten	2.20	2.80	2.26	3.91	2.07	3.54
„ per cent. of True Gluten	—	27.04	—	42.54	—	35.43
Glutenin ex gluten	6.67	7.53	3.05	5.28	3.77	6.45
Soluble Extract	4.04	4.71	4.07	7.04	5.91	10.11
„ Protein	1.24	1.45	0.34	0.59	0.40	0.69
Reducing Sugars	1.09	1.27	0.63	1.15	0.47	0.80
Non-reducing Sugars	0.16	0.19	1.54	2.67	2.56	4.38
Acidity as Lactic Acid	—	—	—	—	0.084	0.144

	No. III.		No. IV.		No. V.	
Moisture	43.65	—	44.49	—	44.55	—
Gluten, Wet	20.3	35.93	13.78	24.80	19.92	35.86
„ Dry	6.26	11.08	4.84	8.71	6.10	10.98
„ True	5.73	10.14	4.29	7.72	5.25	9.45
Gliadin ex gluten	1.81	3.20	1.17	2.10	1.74	3.13
„ per cent. of True Gluten	—	31.55	—	27.21	—	33.12
Glutenin ex gluten	3.92	6.94	3.11	5.60	3.51	6.32
Soluble Extract	3.81	6.73	3.97	7.14	3.50	6.30
„ Protein	0.50	0.88	0.55	0.98	0.40	0.72
Reducing Sugars	0.04	0.07	0.40	0.72	0.20	0.36
Non-reducing Sugars	0.58	1.02	0.33	0.60	0.35	0.63
Acidity as Lactic Acid	0.09	0.159	0.09	0.162	0.09	0.162

	No. VI.		No. VII.		No. VIII.	
Moisture	43.68	—	44.35	—	43.28	—
Gluten, Wet	19.16	33.91	19.20	34.56	19.88	34.99
„ Dry	6.02	10.97	5.91	10.64	6.01	10.58
„ True	5.40	9.56	5.34	9.61	5.41	9.52
Gliadin ex gluten	1.94	3.43	1.96	3.53	2.14	3.77
„ per cent. of True Gluten	—	35.87	—	36.73	—	39.60
Glutenin ex gluten	3.46	6.12	3.38	6.08	3.27	5.75
Soluble Extract	4.28	7.57	4.63	8.33	4.94	8.69
„ Protein	0.40	0.71	0.34	0.61	0.40	0.70
Reducing Sugars	0.35	0.62	0.86	1.55	0.51	0.90
Non-reducing Sugars	0.54	0.95	0.74	1.33	0.67	1.18
Acidity as Lactic Acid	0.09	0.159	0.09	0.162	0.09	0.158

The moisture in the doughs cannot be regarded as absolutely exact, since there is a difficulty in obtaining a perfectly fair sample: there must also be a slight loss through continued fermentation in the hot-water oven. An examination of these results shows that a greater quantity of wet gluten was obtained from all the doughs, except No. IV., than was obtained from the flour. In No. IV. there is a very marked diminution. Speaking generally the dry glutens are slightly lower than in the flour, thus showing that as a result of fermentation the water-retaining power of the gluten is increased. As might be expected, the dry gluten also of No. IV. is much less. The ratios of wet to dry gluten of Nos. O., I., III., and IV., are as follows: 2.70, 3.22, 3.24, 2.85. It will be seen that the water-retaining power of the gluten has receded under the long fermentation of No. IV. to practically the same as that of the flour. In all the doughs there is a diminution of true gluten. The proportion of protein dissolved from the wet gluten by treatment with 70 per cent. alcohol in the manner described is much less than that obtained by extraction of the flour direct by the methods usually adopted. These results are therefore not comparable with those of gliadin ex flour, but may be compared among themselves. The most instructive comparison is probably that of the various percentages of gliadin in true gluten with each other. Of the flour true gluten, 27.04 per cent. was thus dissolved. In the dough treated with salt, No. II., this figure had increased to 42.54, while in No. III. it was also high. In No. III. there is an increase of the soluble gluten over that in the flour, while with the over-fermentation of No. IV. the soluble portion of the gluten has diminished. A possible explanation of this is that in washing this long-acted-on gluten some of the gliadin is lost by washing away. In all the glutens from the more normally fermented doughs, there is an increase in the proportion which is soluble. Chalk removes some of the gliadin from solution by adsorption. These gliadin results are therefore too low, but are nevertheless comparable among themselves.) In the soluble extracts, that of the flour is 4.71, a figure materially increased in the salt made dough: it is very probable this would have been more in a dough made from flour and water only. The addition of malt flour, as might be expected, caused a still further increase in the amount of soluble matter present. The malt flour used had a diastatic capacity of 48.6° Lintner, and 31.93° when tested with ordinary starch solution instead of that of soluble starch. Although in all the fermentation tests there was a destruction of some of the soluble matter by the yeast, yet that remaining is more than the soluble matter of the flour itself. In every case there is much less soluble protein obtained from the doughs than from the original flour. The reducing sugars are calculated as maltose from the cupric reducing power of the solutions in each case. It is difficult to see why this should have been less in Nos. II. and III., but still the fact remains.

In the fermented doughs, hydrolysis of starch and fermentation of sugar are proceeding together, and except in No. VII., the combined causes have caused a diminution in the reducing sugars. The solutions were in all cases inverted in the ordinary manner by the addition of hydrochloric acid and heating to 68° C. The consequent increased cupric reducing power was ascribed to the presence of cane sugar and calculated as such. Here again there are some anomalies, as the flour yielded only 0.19 per cent. of non-reducing sugar. Under the influence of salt, No. I., and salt and malt, No. II., this figure increased in these doughs to 2.67 and 4.38 respectively. This treatment can scarcely be expected to have actually resulted in the production of cane sugar. It is suggested as a

VARIOUS DATA OF DOUGHS.

	No. I.	No. II.	No. III.	No. IV.	No. V.	No. VI.	No. VII.	No. VIII.
Solids of doughs calculated from weights taken, per cent	57.44	57.38	57.00	57.30	57.30	57.30	57.15	57.30
Water of doughs calculated from weights taken, per cent	42.56	42.62	43.00	42.70	42.70	42.70	42.85	42.70
Solids determined on new-made dough, per cent	57.28	57.79	—	—	57.50	57.50	57.66	58.24
Water determined on new-made dough, per cent	42.72	42.21	—	—	42.50	42.50	42.34	41.76
Loss of dough in making, in grams	1.0	2.0	2.5	2.8	1.4	2.7	3.5	3.9
Dough taken for fermentation, in grams	292.0	294.0	297.3	297.7	296.1	297.7	296.9	299.0
Loss of weight during fermentation, in grams	0.40	1.50	4.00	4.60	3.80	3.20	5.40	5.60
Volume of gas evolved at 18.0° C. and 760 m.m. pressure in c.c.	0.00	0.00	1,670	2,609	1,820	1,827	2,387	1,836
Weight of gas, CO_2, evolved, in grams	0.00	0.00	3.09	4.71	3.37	3.38	4.42	3.39
Approximate weight of sugar required for production of gas, in grams ..	0.00	0.00	6.68	10.40	7.28	7.31	9.55	7.34
Approximate weight of alcohol produced, in grams	0.00	0.00	3.34	5.20	3.64	3.65	4.77	3.67
Weight of alcohol produced per 100 grams of dough, *i.e.* per cent	0.00	0.00	1.12	1.76	1.24	1.22	1.65	1.22
Loss of weight during fermentation, per cent	0.13	0.51	1.34	1.56	1.28	1.07	1.82	1.87
Sum of the two preceding quantities	0.13	0.51	2.46	3.32	2.52	2.29	3.47	3.09
Weight of sugar required per 100 grams of dough, *i.e.* per cent	0.00	0.00	2.24	3.53	2.48	2.45	3.21	2.45
Difference between the two preceding quantities	0.13	0.51	0.22	—0.21	0.04	—0.16	0.26	0.64
Soluble extract of the fermented dough, per cent	4.07	5.91	3.81	3.97	3.50	4.28	4.63	4.94
Subtract soluble matter of unfermented dough, per cent	3.29	3.33	3.29	3.29	3.89	3.92	3.28	3.91
	0.78	2.58	0.52	0.68	—0.39	0.36	1.35	1.03
Add sugar required for production of gas, per cent	0.00	0.00	2.24	3.53	2.48	2.45	3.21	2.45
Soluble matter produced during fermentation of dough, per cent	0.78	2.58	2.76	4.21	2.09	2.81	4.56	3.48
Ditto calculated on water-free solids of dough, per cent	1.35	4.41	4.88	7.58	3.76	4.97	8.21	6.12

possible explanation that the soluble extract may have consisted in part of soluble starch or some of the higher and unstable dextrins, and that these were converted into maltose by the hydrochloric acid, and hence the considerable increase in cupric reducing power. In the case of all the fermented doughs, there is an increase in the non-reducing sugars, determined in the same manner. The acidity results are rather surprising, as in all, including the very long fermentation, No. IV., the quantity obtained is practically the same.

Further Data on Doughs.—With the aid of the preceding tables some further data may now be given of these doughs. These follow and are mostly self-explanatory. The weights of raw materials are given, and also that of the dough, showing the loss incurred in making. The loss in fermentation is that obtained by direct weighing before and after. The volume of gas was that read off in c.c. in each experiment. This was converted into grams by multiplying by the factor, 0.00185. As 100 grams of sugar are required for the production of 46.4 grams of carbon dioxide, the number of c.c. of gas, multiplied by the factor 0.004, gives the weight of sugar required for its production. The alcohol produced may be taken as about one-half the sugar required. The figures obtained in this manner must be regarded as only approximate, but represent with a reasonable degree of accuracy the results in the particular experiments. The soluble extract of the fermented dough is calculated from that of its constituents, while that of the unfermented dough was directly determined.

There was a certain amount of loss in weight during the time of remaining in the fermenting apparatus even with the doughs which contained no yeast. In the fermented doughs, the loss in weight varied from 3.20 to 5.60 grams, or 1.07 to 1.87 per cent. The weight of carbon dioxide evolved varied from 3.09 to 4.71 grams, and in most cases very nearly agreed with the loss in weight of the dough. Apparently therefore very little escapes from the dough during fermentation except the gas produced, the alcohol remaining in the dough. The determined loss of weight and calculated amount of alcohol produced together are in close agreement with the sugar which has disappeared. From the foregoing data it was possible to arrive at approximately the amount of matter rendered soluble during fermentation. On subtracting the soluble matter of the unfermented dough from that found after fermentation, and then adding on the sugar which has been decomposed into gas and alcohol, the resultant figure is that required. Except in the case of No. V., where sugar was added to the dough, the soluble matter of the fermented is greater than that of the unfermented dough, notwithstanding the continuous diminution of same by gas production. It will be first of all interesting to observe the respective amounts of hydrolysis in each case. With the flour inself there is a noticeable increase, 1.35 per cent. of its water-free solids having been rendered soluble. As might be expected, the malt flour in No. II. greatly increased this figure. Fermentation for 6 hours resulted in rather more soluble extract, while the figure was much more with the longer fermentation. The addition of sugar to the dough lessened the amount of soluble matter produced by fermentation. That with gelatinised starch, No. VI., is very nearly the same as the plain dough, No. III. In No. VI., where malt flour has been added, the production of soluble matter has been very high; in the case of No. VIII., containing both malt flour and gelatinised starch, there is less conversion during fermentation, but still considerably more than in the dough with gelatinised starch alone. The amount of residual soluble matter after fermentation affords some guide as to the factors governing the probable moisture and flavour character of the resultant bread. Comparing Nos. III. and IV., the much prolonged fermentation of the latter has not diminished the amount of soluble matter remaining in the fermented dough, the figures being 3.81 and 3.97 per cent. In other words, the production of soluble matter by hydrolysis has more than kept pace with its removal by fermentation in the longer time. The addition of sugar in No. V. has not resulted in an increase of residual soluble matter. With gelatinised starch there is a slight increase. Malt flour shows a high figure of soluble matter, which is still higher when gelatinised starch has also been added. Summarising the results under three heads:—

I. *Stimulus to Fermentation.*—Both sugar and gelatinised starch cause a slight increase, malt flour alone a very large increase.

II. *Stimulus to Hydrolysis* (production of soluble matter).—Rather less when sugar has been added. Much increased by malt flour, and also increased by same, though to less extent when gelatinised starch is also added.

III. *Effect on Residual Soluble Matter.*—Not increased by this amount of sugar, increased by gelatinised starch, still more by malt flour, and yet more by malt flour and gelatinised starch conjointly.

523. Further Experiments on Diastatic Action.—In order to study more closely the exact effects produced in bread-making by the action of diastase, the following experiments were made:—Diastase was first extracted from malt by Lintner's process of treating the ground malt in the cold for 12 hours with 20 per cent. alcohol: this was filtered off and precipitated with concentrated alcohol. The precipitate was collected on a filter, washed first with absolute alcohol, then with ether, and dried over sulphuric acid *in vacuo.* This preparation is termed malt diastase. From a sample of low-grade spring American flour, flour diastase was prepared in a precisely similar manner. From malt a fresh 10 per cent. cold-water infusion was prepared and filtered; this is termed malt infusion. No. 4 preparation is a commercial product sold as "diastase," and obtained by evaporating a cold-water infusion of malt to the consistency of a syrup *in vacuo.* The fifth was a high-class sample of guaranteed pure malt extract.

Their diastatic value was first determined by Lintner's process on soluble starch, with the following results:—

		Diastatic Value.
No. 1.	Malt Diastase	266.6° Lintner.
" 2.	Flour Diastase	228.5° "
" 3.	Malt Infusion	15.6° "
" 4.	"Diastase"	222.2° "
" 5.	Malt Extract	3.1° "

It was decided to make a series of baking tests with these substances, taking such quantities as would contain throughout the same number of units of diastatic activity: knowing the diastatic value of each, it becomes a matter of simple calculation to determine what quantities must be taken in order to attain this object. Taking the malt diastase as a standard, the amount of 0.125 gram was fixed on: the equivalent quantities of the others were as follows:—

No. 1.	Malt Diastase	0.125 gram.
" 2.	Flour Diastase	0.145 "
" 3.	Malt Infusion	21.36 c.c.
" 4.	"Diastase"	0.153 gram.
" 5.	Malt Extract	10.75 grams.

For baking tests the following quantities were taken:—

Flour, equal quantities of Spring American and English wheat patents	140	grams.
Water, in which was included solutions of the equivalent quantity of each diastatic body	80	“
Compressed yeast	10	“

In one series of tests, *a,* the diastatic ingredient was in its normally active state: in a second series, *b,* precisely similar in every other respect, the diastatic solution was first placed in a boiling water bath for 5 minutes with the object of destroying the diastase, and subsequently cooled prior to mixing it in with the flour and yeast. A plain loaf, No. 6, was also made from flour, water, and yeast only.

The doughs were allowed to ferment at a moderate temperature, and the following observations made on their being ready to go into the oven.

No. 1. Difference between *a* and *b* very marked; *a* slacker and more sticky.
“ 2. Very slight difference, if any.
“ 3. *a,* slightly sticky, difference between it and *b* not very marked.
“ 4. Clearly marked difference between *a* and *b.*
“ 5. *a,* fairly stiff, not sticky; *b,* tougher than *a*; both brown in colour as a result of presence of extract.
“ 6. Plain loaf. Compared with all others, stiff.

The loaves were baked in a moderate oven for 45 minutes, and were of Coburg shape, giving as much facility for expansion and formation of crust as possible.

The following was the character of the crust:—

No. 1. *a* browner than *b.*
“ 2. No difference between *a* and *b*: both much like No. 6.
“ 3. *a* slightly browner than *b.*
“ 4. *a* slightly browner than *b.*
“ 5. Both full brown in colour of surface, and dark in breaks: *a* browner than *b.*
“ 6. Plain loaf.

As a rule the crusts of series *a* seemed more pliable than those of *b.* Throughout the whole series, with the exception of the No. 2's, there was a distinct difference of flavour distinguishable before the loaves were cut.[1]

The crumb of each had the following characters:—

No. 1. Good volume: *a* in centre sticky and gummy; *b,* better colour. Flavour in both decidedly sweet, but far more so in *a.*
“ 2. *a,* only slightly sweeter than *b*; *b,* better colour, both slightly darker than No. 6.
“ 3. *a,* sweet and malty; *b,* ditto in less degree, and slightly better in colour.
“ 4. *a* has more flavour than *b,* and is also very slightly better in colour than *b.* Duplicate loaves were baked with No. 4 to see if the colours were relatively the same. Found *b* again to be darker than *a,* and of considerably less volume.

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[1] This is a somewhat curious instance of the baker's use of the term "flavour": bakers habitually examine bread in the first instance by the smell of a loaf, and judge flavour through its subtle association with smell. Such flavour judgment may be described as "how the bread tastes to the nose."

No. 5. Both *a* and *b* were brown, with very slight difference in colour. Flavour of *b* distinctly that of malt extract. Flavour of *a* different, being that of malt extract with an additional flavour of a more purely saccharine character (doubtless the result of the presence of sugars of conversion).

" 6. Plain loaf, slightly yeasty in flavour.

A portion of each sample of bread was taken, dried to a constant weight in the hot-water oven, finely powdered, and stored in stoppered bottles. A soluble extract was prepared from each in the following manner:—10 grams of the powdered solids were taken during the afternoon, mixed with 100 c.c. of cold water, and vigorously shaken several times during the afternoon and evening. They were then allowed to stand overnight, and the supernatant-liquid decanted in the morning, without disturbing the residue, and filtered. A portion of this was evaporated to dryness for soluble extract, and the maltose determined in another portion. The following are the results of analysis expressed in percentages on the dried solids:—

ANALYSES OF DIASTASE BREADS.

No.	Variety.	Soluble Extracts.		Maltose.		
		a	b	a	b	a-b
1	Malt Diastase	27.24	8.04	7.83	2.90	4.93
2	Flour Diastase	10.40	9.65	1.61	1.61	0.00
3	Malt Infusion	17.75	10.55	4.44	3.63	0.81
4	"Diastase"	9.20	6.12	2.5	1.13	1.37
5	Malt Extract	16.04	8.76	5.60	3.23	2.37
6	Plain Loaf	7.60	—	1.61	—	—

In examining these results, the first noticeable point is that in No. 1, *b*, there is a considerable quantity of maltose over that in No. 6. The same is particularly observed also in No. 3: it would seem therefore that the means employed in order to destroy saccharifying action were not sufficient. As No. 3 was by far the largest amount of liquid solution of diastatic ingredient acted on, its temperature was taken at the end of the five minutes in the water-bath, and found to be 198° F.; at the same time there was an abundant flocculent precipitate of coagulated proteins. That the maltose in No. 3, *b*, is the highest of that series also points to insufficient heating, for the other solutions, which were considerably less in volume, had apparently much more of their diastatic action destroyed.

The following are the approximate percentages of maltose in each bread, due to that actually added in the extract preparation:—

	Maltose.
No. 1. Malt Diastase	0.00
" 2. Flour	0.00
" 3. Malt Infusion	0.38
" 4. Diastase	0.08
" 5. Malt Extract	5.10

In the last case the maltose thus added is very nearly the whole of that found in No. 5, *a*, and more than in No. 5, *b*. The mode of extraction employed, although giving strictly comparative results, does not however remove the whole of the maltose in solution from the solids. The vesicular nature of bread, in which the various constituents are locked up within films of coagulated protein matter, makes the entire extraction of the soluble ingredients a task of considerable difficulty and uncertainty.[1]

The column headed *a-b*, gives the maltose due to conversion of starch though not necessarily the whole of such maltose.

524. Highly Diastatic Malt Extracts.—The preceding experiments throw a light on the effects produced by highly diastatic extracts during bread-making. Taking the column, *a-b*, malt diastase prepared by extraction and precipitation from the malt as described, effected the production of 4.93 per cent. of maltose. Flour diastase, the quantity of which taken had an equal diastatic value by Lintner's method on soluble starch, effects no conversion whatever. So also the malt infusion effects comparatively little change. It will be remembered that certain forms of diastase are able to convert starch paste, while others can only act on soluble starch (see paragraph 267); raw grain diastase belongs to the latter group, and hence, doubtless, its inability to convert the starch of flour. The diastatic value of any preparation for bread-making depends not simply on its activity as measured on soluble starch by Lintner's method, but on its power of converting starch paste, and even the imperfectly gelatinised starch occurring in bread.

The commercial "diastase," preparation No. 4, is a compound consisting essentially of the concentrated cold-water extract of malt, so prepared as to retain the diastatic activity of malt in the highest possible degree. Various samples have given a diastatic capacity on Lintner's scale varying from about 220° in the lowest to considerably over 300° in the highest. The following is the result of its analysis:—

ANALYSIS OF "DIASTASE."

Constituents.	Whole Extracts.	Dried Solids.
Water	27.90	—
Mineral Matter (Phosphates)	3.32	4.60
Proteins	13.41	18.60
Dextrin	0.40	8.88
Sucrose	2.20	3.05
Maltose	15.09	20.93
Dextrose and Lævulose	31.68	43.94
	100.00	100.00
Cuprous Oxide, Cu_2O, from 100 grams	81.75	113.4
Reducing Sugars, calculated as Dextrose and Lævulose	41.09	56.99

The effect of this body on bread, when taken in a quantity having the same diastatic value as the other substances tested, is much less than that of chemically prepared malt diastase, though much more than the raw flour diastase. This concentrated cold-water extract is therefore to be differentiated from both pure malt diastase and raw grain diastase in its

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[1] The plan of determining soluble extract in dried solids is no doubt responsible for generally low figures. The great advantage of the method is that the solids can be kept in an unaltered form until a convenient time for their analysis arrives. This is obviously impossible with moist breads. Recently the author has, in the absence of enzymes (as in bread analysis), used the modification of direct extraction from moist bread. He then simply places the bread and water together in a flask, adds a few drops of chloroform, corks and shakes, and sets aside without fear of change occurring during an interval of waiting. This is particularly applicable to determinations of maltose.

effects. Its behaviour indicates the presence of a considerable proportion of the non-liquefying form of diastase. At the same time the true liquefying malt diastase is also present, though not to the same extent as in the ordinary malt extract, No. 5, which with the same Lintner value on the quantities taken gave a much higher production of maltose. But against this must be remembered the quantities actually used: of the "diastase" there was only 0.153 gram as compared with 10.75 grams of malt extract. In giving a value to degrees Lintner as a measure of utility of a malt extract to bakers, it may generally be concluded that an extract of say 120° Lintner will produce more maltose in bread-making than one of 60° Lintner, but not so much as double the quantity. The extra diastatic power is probably due in part to liquefying, and therefore saccharifying diastase, and in part to non-liquefying, and therefore non-effective diastase. The use of 2 lbs. of the 60° Lintner malt extract will as a general rule in bread-making convert more starch into sugar than will 1 lb. of the 120° Lintner extract. Further the 2 lbs. will have imparted to the bread all the extra sugar, dextrin, etc., naturally present therein. It must not be forgotten that the flavouring effect of malt extract as a bread improver is largely due to the empyreumatic products resulting from the kiln drying of the malt itself. Everything else being equal, with less malt extract, less of these products will be added to the bread. In addition, in order to secure a high degree of diastase, the malt is usually low kiln dried, and so the empyreumatic products are only very slightly developed. The introduction of a small quantity of a highly diastatic extract at the dough stage suffices for the conversion of a marked amount of starch into dextrin and maltose, thus conferring both moistness and sweetness on the bread. It also exerts a considerable action on the proteins of flour, producing a softening effect on the gluten. In the case where strong, harsh, and dry flours are in use, the result is to make the resultant bread approach far more closely in character to that made from softer and sweeter flours. One word of caution may be here introduced as to the employment of these exceptionally powerful extracts; these preparations are so energetic as to be capable of carrying too far the changes in starch and other flour ingredients, and thus yielding a wet, clammy loaf. The obvious remedy is to employ the substance in less proportion. The precise amount is easily determined by a very few trials.

525. Typical American High-grade Yeast Bread.—Wiley regards the following as representing the average composition of a bread of this type:—

Moisture	35.00	per cent.
Protein	8.00	"
Ether Extract	0.75	"
Starch and Sugar	54.45	"
Fibre	0.30	"
Ash	1.50	"

The ash would approximately consist of 0.50 per cent. derived from the natural mineral ingredients of the flour, and 1.0 per cent. due to the addition of salt. The moisture may rise above 40 per cent. in breads made of flour rich in gluten, or sink to 30 per cent. or under when flour of an inferior gluten content is employed. The ether extract will vary according to the amount of milk or other source of fat employed in making the bread, or in the case of tin bread, in greasing the baking tin.

526. Analyses of Commercial Breads.—The following table gives the results of analyses by the authors of a number of samples of bread bought for that purpose. They were in all cases ordinary shop products, and were purchased without giving any intimation of the object for which they were procured, either to the bakers or the manufacturers of the flours. The results of the analyses are given on the whole breads, and also as calculated on the water-free solids. The energy in Calories is also given. For this purpose the whole of the carbohydrates, including cellulose, are reckoned together.

Names of Breads.

No. 1. Best white bread.
" 2. London households.
" 3. Whole-meal bread.
" 4. Bermaline bread.
" 5. Hovis bread.
" 6. Daren bread.
" 7. Veda bread.
" 8. Turog bread.

ANALYSES OF COMMERCIAL BREADS.

Constituents.	No. 1. As Bought	No. 1. Water Free.	No. 2. As Bought	No. 2. Water Free.	No. 3. As Bought	No. 3. Water Free.	No. 4. As Bought	No. 4. Water Free.
Moisture	38.35	—	40.00	—	44.56	—	42.94	—
Proteins, Soluble ..	0.42	0.68	0.57	0.95	0.57	1.03	0.35	0.61
Proteins, Insoluble ..	6.62	10.73	7.93	13.22	7.13	12.86	6.69	11.72
Starch, Cellulose, etc.	45.53	73.86	40.48	67.47	33.20	59.89	32.39	56.69
Maltose	4.44	7.22	3.58	5.96	6.70	12.08	7.03	12.32
Other Soluble Matters	2.82	4.57	5.95	9.92	4.29	7.74	7.78	13.63
Phosphoric Acid ..	0.09	0.14	0.18	0.30	0.46	0.83	0.42	0.74
Other Mineral Matter	0.71	1.15	0.50	0.83	0.89	1.60	0.70	1.32
Acidity as Lactic Acid	0.25	0.40	0.24	0.40	0.45	0.81	0.40	0.70
Fat	0.77	1.25	0.57	0.95	1.75	3.16	1.30	2.27
Energy in Calories	251.7	—	243.9	—	229.2	—	234.5	—

	No. 5.		No. 6.		No. 7.		No. 8.	
Moisture	47.81	—	45.02	—	32.57	—	46.82	—
Proteins, Soluble ..	0.35	0.67	1.17	2.12	0.90	1.33	0.58	1.09
Proteins, Insoluble	9.26	17.74	7.83	14.24	8.49	12.59	8.72	16.39
Starch, Cellulose, etc.	27.21	52.15	24.07	43.78	16.38	24.29	36.68	68.97
Maltose	6.46	12.37	6.81	12.40	19.87	29.47	3.40	6.39
Other Soluble Matters	6.15	11.80	12.22	22.22	20.03	29.71	1.78	3.35
Phosphoric Acid ..	0.43	0.83	0.56	1.02	0.41	0.61	0.39	0.74
Other Mineral Matter	0.60	1.13	0.72	1.31	0.59	0.88	0.53	0.99
Acidity as Lactic Acid	0.43	0.82	0.40	0.73	0.51	0.75	0.50	0.95
Fat	1.30	2.49	1.20	2,18	0.25	0.37	0.60	1.13
Energy in Calories	214.7	—	239.0	—	304.3	—	215.3	—

527. Bread Improvers.—In the manufacture of bread, the addition of certain other substances than flour and water is a recognised and integral part of the manufacture. When brewer's yeast was the only type used, some yeast stimulant was absolutely necessary for reasons already explained (paragraphs 375-8). Potatoes were found exceedingly useful and convenient for the purpose, and accordingly the potato ferment was at one time a regular part of the process of bread-making. With the use of distiller's yeast, the necessity of some stimulant for the yeast no longer existed, and accordingly potatoes have largely gone out of use. But there are other functions in bread-making fulfilled by the potato, and these continue to require attention. Substances added for the purpose of effecting improvements in bread may be grouped into the following classes:—

Milk.—Whole, dried, or separated; improves flavour, appearance and nutritive value.

Butter.—This and other fats improve flavour and shorten crust, thus preventing toughness.

Moistness-retaining bodies.—In their pure state, some flours, and particularly those which are the most nourishing as a result of their high percentage of proteins, produce a bread which readily becomes somewhat dry and harsh. To remedy this, an increase in the quantity of gelatinised starch and dextrin removes harshness and makes the bread remain moist and taste moist much longer.

Potatoes.—The ordinary boiled potato has the effect just mentioned. As a substitute, it has been proposed to dry potatoes and grind them into a meal or flour. Such a preparation, however, only adds starch in the ungelatinised form, and cannot increase the moistness as a consequence. Whatever soluble constituents the potato contains are thus introduced into the bread. Recently, preparations have been placed on the market which consist of thoroughly cooked potatoes, dried and reduced to a fine powder. These are capable of acting as a direct substitute for the boiled potato, introducing the same substances and avoiding the mess and dirt which almost of necessity accompany the cooking of potatoes in a bakehouse.

Gelatinised Starches.—Among members of this group, the use of scalded flour is pre-eminent. This adds gelatinised starch, which may be used in a ferment, or if wished may be added to the dough. Scalded rice and maize also produce the same effects. The employment of all or any of these has the advantage of greater cleanliness in manipulation than occurs with potatoes. All are sources of gelatinised starch. Certain grains and other starchy bodies are now gelatinised, dried off and sold in the form of thin flakes. These may be used as ready-gelatinised forms of starch which require no cooking.

Dextrinous bodies.—From its well-known gummy properties, dextrin serves to keep bread moist. Its principal sources in bread are, starch which has been converted into dextrin by enzymes, malt extract, and so-called confectioners' glucose, which is really almost entirely composed of dextrin and maltose (see Chapter XXVIII.).

Sweetening bodies.—Sweetness may be conferred by the addition of pure sugar or by the use of malt extract or "glucose," both of which contain maltose in large quantities. When gelatinised starch is acted on by diastase, more or less maltose is formed. Maltose may be thus produced from the starch of the flour itself, or from that added in the gelatinised condition from any other source. In addition to its flavouring properties, sugar serves the yeast as a source of carbon dioxide gas.

Diastatic bodies.—Various enzymes serve the purpose of converting starch into dextrin and maltose. Flour itself contains a considerable quantity of diastase. Carefully prepared malt extract is also actively diastatic, while certain special forms contain diastase in a very concentrated degree. Malt flour, particularly that of air-dried malt, is also rich in diastatic power. All these substances are used for bread-making purposes. In addition to the starch converting diastase, these bodies may contain more or less of proteolytic enzymes by which the gluten of flour is affected. The charges thus produced may be beneficial or otherwise according to the nature and quality of the gluten.

Mineral bodies.—First among these is common salt, which in addition to its flavouring properties acts as a binding or strengthening agent on the dough. Certain other mineral bodies have beneficial effects on bread. One of these is calcium chloride, which in small quantities serves as a strengthening agent, and also may be useful as a source of lime for nutritive purposes. In its general properties calcium chloride falls into somewhat the same category as salt. Magnesium sulphate is at times employed, more especially it is said in some of the Midland counties of England. For reasons already given, the addition of phosphates and phosphoric acid serves to effect some improvements in bread.

Yeast nourishing bodies.—Several of the substances already mentioned are of service as direct or indirect yeast foods; among these are sugars and the bodies from which derived, the diastases which produce sugar, and some mineral salts. In addition to these some bodies rich in organic nitrogenous constituents are of value as food and stimulants for yeast.

528. **Malt Extract.**—This being one of the substances most largely used for the improvement of bread, its preparation and properties require a somewhat extended description. Malt extract is prepared by evaporating at a low temperature *in vacuo* the filtered wort from mashed malt until the resultant liquid is of the consistency of a thick syrup. In order to investigate the composition of malt extract under different conditions, the following experiments were made:—

A high quality sample of pale malt was finely ground; and of this 500 grams were taken, mixed with 2,000 c.c. of water, and mashed for 2 hours, at a temperature of 60° C., in a water-jacketed pan. The resultant wort was then filtered bright, and the "grains" washed, dried and weighed, their weight being 113 grams, showing that over 75 per cent. of the malt had gone into solution. This wort was called Preparation I., Unevaporated. A portion was reserved for analysis, and the remainder evaporated *in vacuo,* the operation being pushed as far as possible: this constituted Preparation I., Evaporated.

Another 500 grams of the malt were then taken, mixed with 2,000 c.c. cold water, continually stirred during 3 hours, and then allowed to stand overnight. The clear liquid was poured off in the morning, the residual malt drained moderately dry. The liquid was filtered bright, and constituted Preparation II., Unevaporated. A part of this was evaporated in precisely the same manner as with No. I., and is termed Preparation II., Evaporated.

The residual malt from No. II. was next taken, mashed with 2,000 c.c. more water for 6 hours, at 60° C., and then raised to 100° C., and filtered bright. This constituted Preparation III., Unevaporated. A portion was evaporated *in vacuo* as before, and this formed Preparation III., Evaporated.

Each of these was then subjected to analysis, determinations being made as given in the table of analyses following, in which are also included similar analyses of commercial samples of guaranteed pure malt extract.

Various determinations, as given below, were made on the Unevaporated Preparations.

	No. I.	No. II.	No. III.
Specific gravity at 15.0° C.	1,057.5	1,020.7	1,050.0
Dry Solids, grams per 100 c.c. calculated from gravity	14.93	5.37	13.00
Dry Solids, grams per 100 c.c. by evaporation and weighing	14.06	4.93	12.78
Dry Solids, weight in percentages ..	13.30	4.83	12.17

The method of analysis employed is that described in Chapter XXIV., and is subject to the limitations of accuracy there explained. It should be mentioned that all the figures, both on the liquids and the extracts, are the results of direct determinations; the percentage composition of "Dried Solids" being calculated from those obtained in the liquid or extract with water present. The dextrin was precipitated by alcohol and corrected for solubility and amount of precipitated protein: it no doubt contains not only pure dextrin, but also the other gum-like substances frequently returned as "indeterminate bodies."

The No. I., or whole extract, contained sucrose in the wort, but this disappeared during concentration. The glucoses also show a diminution, while dextrin increases. The dextrin precipitate in the evaporated extract was much darker, and evidently contained a considerable proportion of products of caramelisation.

The cold water extracts, No. II., are very interesting. The proteins and phosphates are very high: so also is the sucrose, which, however, diminishes on cencentration. The quantity of maltose is very small, while the glucoses represent about half the total weight of the solids present. The sugars here again diminish during concentration, while dextrin increases, no doubt for the same reason as in No. I.

In No. III., as might be expected, sucrose is absent, any traces in the original solution being doubtless destroyed during the prolonged mashing. Glucose (dextrose) and lævulose are present in very small quantity, the sugar being almost entirely maltose. As might be expected, the dextrin is high, and the act of concentration has produced practically no alteration in the proportions of the constituents present, the lengthened period of mashing and subsequent boiling having reduced all bodies present to a stable condition.

The above three types of extract are sometimes called—

No. I. Whole extract, being the entire extract of the malt.

No. II. Cold water extract, from the fact of its containing the cold water soluble constituents only.

No. III. Spent extract, being prepared from the comparatively spent grains after extraction with cold water. This is also sometimes called a "split" extract, since the products of the malt are split into two separate lots in its production.

All three of these are more or less represented in commercial extracts, the first being the older and purely normal type of the whole malt. With the demand for extracts of high diastatic power, No. II. type came into the market. The manufacture of No. II. made the preparation of No. III. a necessity in order to utilise the very large proportion of residual matter from making the cold water extract.

In diastatic power, No. I., if properly prepared and carefully concentrated, should be of fair quality. No. II. will be of very high diastatic value, while No. III. will be devoid of any diastatic power whatever.

Modern manufacturing processes are a combination of the various methods described, mashing being made at various temperatures, or at a lower than normal temperature in order to retain diastase; while a good deal of the purely saccharine extract is sacrificed, or obtained in a further extraction, when it may or may not be mixed in with the first or more diastatic extract.

The samples of commercial extract call for but little remark; in the first, the dextrin is fairly high, and so also is the maltose; sucrose, dextrose, and lævulose being present in small quantity. At the same time, the sample is well concentrated, but 22.23 per cent. of water being present. With any less moisture the extract would be too stiff to pour out of tins or drums when cold. The second commercial sample affords evidence of having been worked at a higher temperature, although the degree of concentration is less. Both these extracts show all signs of being nothing beyond pure, normal extracts of malt.

In breadmaking, the addition of malt extract, in the first place, increases, to the extent to which it is used, the quantities present of the various ingredients of the extract, among which are sugars which impart sweetness; dextrin, by which the bread is caused to remain moister; and phosphates, which add to the bone-forming materials, and also act as a yeast stimulant. There is in addition the specific effect on the constituents of the flour caused by the diastase present in the extract.

Analyses of Malt Extract Preparations.

Constituents.	No. I., Unevaporated.		No. I., Evaporated.	
	Whole Liquid.	Dried Solids.	Whole Extract.	Dried Solids.
Water	86.70	—	14.70	—
Mineral Matter (Phosphates)	0.24	1.77	1.70	1.99
Proteins	0.86	6.44	5.27	6.18
Dextrin	1.32	9.95	10.82	12.68
Sucrose	0.43	3.23	Absent	Absent
Maltose	9.04	68.03	60.97	71.48
Glucose and Lævulose	1.41	10.58	6.54	7.67
	100.00	100.00	100.00	100.00
Cuprous Oxide, Cu_2O, from 100 grams	13.99	105.2	87.50	103.70
Reducing Sugars, calculated entirely as Maltose	11.30	84.98	70.67	82.85
	No. II., Unevaporated.		No. II., Evaporated.	
Water	95.17	—	22.90	—
Mineral Matter (Phosphates)	0.32	6.52	4.80	6.23
Proteins	0.80	16.56	12.71	16.49
Dextrin	0.60	12.36	13.66	17.72
Sucrose	0.45	9.31	4.79	6.21
Maltose	0.21	4.20	2.69	3.48
Glucose and Lævulose	2.45	51.05	38.45	49.87
	100.00	100.00	100.00	100.00
Cuprous Oxide, Cu_2O, from 100 grams	5.11	106.43	79.49	103.10
Reducing Sugars, calculated entirely as Glucose and Lævulose	2.57	53.66	40.08	51.99
	No. III., Unevaporated.		No. III., Evaporated.	
Water	87.83	—	11.20	—
Mineral Matter (Phosphates)	0.17	1.40	1.11	1.24
Proteins	0.44	3.61	3.37	3.79
Dextrin	2.44	20.03	17.40	19.60
Sucrose	Absent	Absent	Absent	Absent
Maltose	8.82	72.45	66.06	74.40
Glucose and Lævulose	0.30	2.51	0.86	0.97
	100.00	100.00	100.00	100.00
Cuprous Oxide, Cu_2O, from 100 grams	11.52	94.67	83.5	94.03
Reducing Sugars, calculated as Maltose	9.31	76.48	67.44	75.94
	FIRST COMMERCIAL EXTRACT.		SECOND COMMERCIAL EXTRACT.	
	Whole Extract.	Dried Solids.	Whole Extract.	Dried Solids.
Water	22.23	—	27.64	—
Mineral Matter (Phosphates)	1.10	1.42	1.40	1.93
Proteins	3.01	3.88	4.74	6.55
Dextrin	12.90	16.59	5.80	8.02
Sucrose	3.59	4.61	1.92	2.66
Maltose	54.84	70.51	53.65	74.14
Glucose and Lævulose	2.33	2.99	4.85	6.70
	100.00	100.00	100.00	100.00
Cuprous Oxide, Cu_2O, from 100 grams	72.5	93.22	80.0	110.5
Reducing Sugars, calculated as Maltose	58.55	75.28	64.61	89.29

The Nutritive Value and Digestibility of Bread.

529. Nutrition and Food.—Nutrition may be regarded as the process of supplying the materials necessary in order to effect the growth and development of living organisms, and the maintenance in a healthy condition of those organisms when fully developed. The human organism is for practical purposes the only being whose requirements need be here considered. Food may be regarded as that which when taken into the body provides material for its growth and development, the reparation of the waste of its tissues, the production of heat, and the energy necessary both for internal and external muscular work. In other words food comprises those substances which are available for purposes of nutrition.

Food substances or "nutrients" are derived from the animal, vegetable, and mineral kingdom. They belong to the following chemical groups of substances—proteins and closely allied bodies, as sclero-proteins (gelatin), carbohydrates, fats, and mineral matters, especially those containing lime, potassium, sodium, phosphorus, and chlorine, also water. An old classification of nutrients was into flesh formers, as proteins; heat-formers, as carbohydrates and fat; and bone-formers, as calcium phosphate. A more modern arrangement is into the two groups of tissue-formers and work and heat producers as under:—

Tissue-formers.	Work and Heat Producers.
Proteins.	Proteins.
Mineral Matters.	Sclero-Proteins.
Water.	Carbohydrates.
	Fats.
	(?) Mineral Matters and Water.

The proteins are distinguished from among the other organic constituents of food by their being capable of exercising both the above-mentioned functions of nutrition.

In estimating the nutritive value of foods they are subjected to tests of three kinds:—

I. Chemical analysis, by which the proportions of the various constituents are determined.

II. The heat produced by their combustion in oxygen, this being a measure of their heat and energy producing capacity.

III. Physiological tests, in which their degree of capacity for utilisation by the body is measured.

The general composition as ascertained by chemical analysis need not be further enlarged on here.

530. Heat of Combustion.—This requires some further description. Excluding the mineral matters and water, the other food constituents are all combustible, and each variety evolves a definite amount of heat when completely burned, depending on its composition. The unit measure of heat is that which is required to raise 1 gram of water from 0° to 1° C., and this is called a "calorie." For food valuations a larger unit is convenient; and accordingly, that selected is the large or kilo-calorie, which is the amount of heat necessary to raise 1 kilogram (1,000 c.c.) from 0° to 1° C. The kilo-calorie or large Calorie is indicated by its being spelled with a capital C. When burned with an excess of oxygen the whole of the constituents of any food are completely oxidised; but when consumed in the body, they are finally excreted in only a partially oxidised state, and therefore some allowance must be made for the heat still remaining unused in these bodies. That having been done, the amount of energy liberated by any food follows just the same laws as though it were burned in the ordinary way. The heat liberated within the body by the following substances is, according to Hutchison:—

One gram of Proteins..	4.1 Calories.
„ „ Carbohydrates	4.1 „
„ „ Fat	9.3 „

The energy value of a food is easily calculated from its analysis. If the percentages of proteins and carbohydrates are multiplied by 4.1, and that of the fat by 9.3, the sum of these numbers gives the energy in Calories of the food itself. Thus if a sample of flour gives the following results on analysis, the heat energy is as shown:—

	Per cent.	Factor.	Heat of Combustion.
Protein	11.08 ×	4.1 =	45.428
Carbohydrates	76.85 ×	4.1 =	315.085
Fat	1.15 ×	9.3 =	10.695
Kilo-Calories per 100 grams			371.208
„ „ „ 1 gram			3.71208
Gram-calories per 1 gram			3712.08

Snyder, to whose results a somewhat extended reference follows, returns his "Heat of combustion" in terms of the complete oxidation obtained by burning in oxygen, and without any deduction for incomplete combustion in the body. He uses therefore the following factors for calculating the heat of combustion from the analysis. They are applied to the same analysis of flour.

	Per cent.	Factor.	Heat of Combustion.
Protein	11.08 ×	5.9 =	65.372
Carbohydrates	76.85 ×	4.2 =	322.770
Fat	1.15 ×	9.3 =	10.695
Kilo-Calories per 100 grams			398.837
„ „ „ 1 gram			3.988
Ditto determined direct on the flour			4.032

531. Digestibility.—In making physiological tests this term is used as meaning the measure of the total amount of the food utilised or absorbed by the body. The principle of the determination is the weighing the whole of the food of known composition eaten during a certain period, and the estimation of the weight and composition of that which is ejected in the excreta. The difference is the amount absorbed. The more popular meaning attached to the word digestibility relates to the comparative ease or discomfort with which the food passes through the stomach. In view of the use of the word in this latter sense, Hutchison has proposed to use the word "absorbability" instead of digestibility when dealing with the proportion of a food which is absorbed or utilised by the body. But as most writers still employ digestibility as synonymous with absorbability it will be used in that sense in this work.

532. Amount of Food Required.—To discuss this question adequately would require much more space than can possibly be devoted to it here. The student is therefore referred to *Food and Dietetics* by Hutchison for full information on this subject. From his most interesting book the following summary is quoted:—

"One may sum up the **standard amounts of the different nutritive constituents required daily thus:—**

Protein	125 grams.
Carbohydrate	500 „
Fat	50 „

These would yield the following amount of energy in Calories:—

Protein	$125 \times 4.1 =$	512.5
Carbohydrate	$500 \times 4.1 =$	2050.0
Fat	$50 \times 9.3 =$	465.0
Total	=	3027.5 Calories.

Or, in terms of carbon and nitrogen:—

125 grams of Protein	= 20 grams N and	62 grams C.
500 „ „ Carbohydrate	=	200 „ „
50 „ „ Fat	=	38 „ „
Total	= 20 grams N and	300 grams C.

Such a standard may be regarded as the minimum for a man of average build and weight, and doing a moderate amount of muscular work. . . . In such standards the ratio of protein to carbohydrates and fat taken together is of some importance. It is called the **nutritive ratio.** If 1 part of fat be counted as 2.25 parts of carbohydrate, the nutritive ratio . . . is as 1 to 4.9. In this ratio we have an index of the proportion which the building material of the diet ought to bear to its purely energy-yielding constituents.'' For the figure 4.9, that of 5.3 more closely represents the average ratio of a number of authorities. In the diet of a child the ratio should be approximately as 1 to 4.3.

533. Nutritive Ratio of Wheat Products.—The following figures of analysis are taken from those of spring and winter American wheats and their products:—

	Protein.	Carbohydrates.	Fat.	Nutritive Ratio.
Spring Wheat	14.35	70.37	2.74	1:5.3
Baker's Flour	14.88	69.99	2.00	1:5.0
Patent Flour	12.95	73.55	1.45	1:5.9
Bran	16.28	56.21	5.03	1:4.1
Germ	33.25	35.19	15.61	1:2.1
Winter Wheat	12.43	71.67	2.46	1:6.2
Baker's Flour	13.13	71.52	1.77	1:5.4
Patent Flour	10.18	78.28	1.05	1:7.9

For the moment, neglecting the waste through variations in digestibility, spring wheat and spring wheat baker's flour contain sufficient protein to comply with the standard nutritive ratio. Bran contains a large excess of protein, while that in germ is approximately two and a half times as much as required by the standard. Evidently a mixture of germ and white flour may be made in such proportions as to comply exactly with the nutritive ratio. The spring patent is slightly deficient in protein, but the deficiency is but small. The winter wheat and its products are all lower in protein matter. An interesting point is that the spring patent flour has very nearly the same ratio as the baker's flour from winter wheat. The baker's flours have a slightly higher nutritive ratio than the wheats from which they were obtained, while the ratio is definitely lower in the case of the patent grades. English wheats, and the general average of wheats milled in England, have a lower protein content than spring American wheat. From analysis of a number of representative English millers' flours the following figures have been deduced:—

Moisture	14.0	per cent.
Proteins	11.0	„ „
Carbohydrates	72.7	„ „
Fat	1.5	„ „
Ash	0.5	„ „
Cellulose	0.3	„ „
	100.0	
Nutritive ratio	6.9	

Viewed from the standpoint of a perfectly balanced food, such flour is markedly deficient in fat, and slightly deficient in proteins. In an actual mixed diet, these deficiencies are made up by the addition of butter to bread, and the consumption therewith of such substances as lean meat and cheese.

534. Relative Digestibility of Different Kinds of Bread.—In view of the fact that most wheats and their resultant flours are, as just stated, slightly deficient in proteins, the problem of their nutritive value is largely governed by the extent of that deficiency. American spring wheat, and consequently the whole meal (*i.e.*, meal from the whole wheat kernel, bran and all, or "Graham" flour), contain rather more than the standard proportion. But, as indicated, weaker wheats (*e.g.* American winter) and most wheat mixtures contain less than the standard proportion. Further, in every case the whole wheat contains more protein than the resultant flour. This is a necessary consequence of removing the bran, which is exceptionally rich in protein, during the process of milling. Therefore it has been and is being urged that whole meal bread is more nourishing than that from white flour. Obviously such a comparison can only be made between the products of the same wheat. For example, patent flour from spring wheat contains 12.95 per cent. of protein as against 12.43 in whole winter wheat. But as against this, from each variety of wheat, the whole wheat and the darker coloured baker's flour contain more protein than does the patent or very white flour. In the case of a food it is of importance to know not merely its percentage composition, but also what proportion of it is digested and assimilated by the human alimentary system in order to decide its relative nutritive value. This matter has been made the subject of exhaustive investigation by a number of chemists and physiologists. The following two lines of experiment have been adopted:—

I. Bread is made from the different kinds of flour it is wished to compare. Usually the comparison is between whole meal, and the darker and lighter flours of the same wheat. At times flours of different lengths of extraction have been taken, thus these may consist of say 60, 70, 80 or even a higher percentage of the wheat. Standard digestive mixtures are prepared which resemble as closely as possible the actual digestive juices of the body. These commonly consist of an acid solution of pepsin, as representing the gastric or stomach agent of digestion, and, secondly, an alkaline solution of pancreatin which represents the digestive juices of the portions of the alimentary canal subsequent to the stomach. The bread to be tested is rubbed down to a pulp and the pepsin solution added in measured quantity. A flask containing the mixture is then kept by means of a water-bath at a constant body temperature (98° F. = 36.6° C.) for a definite time, after which the pancreatic solution is added, and the digestive action continued for a further time. At the close, the mixture is filtered and the soluble matter identified and estimated. It is in this way possible to determine what proportion of each bread is thus dissolved by the digestive juices. Objection may be taken that this mode of research cannot be regarded as necessarily exactly doing that which Nature herself does. On the other hand, it does serve to ascertain the actual solubility of, and changes produced in, a particular food under definite conditions. If there is uncertainty as to its being an exact copy of Nature's processes, there is the corresponding certainty that irregularities due to the idiosyncrasies of individuals are eliminated.

Among others, Brunton, Tunnicliffe, and Jago have made extensive investigations in this direction.

II. In the next place digestive experiments have been made on actual human subjects. The general outline of such tests has been to feed healthy individuals on a simple diet, of which the breads under examination form the principal constituent. All the articles of food are carefully analysed, and the quantities given to each subject weighed. The weight and composition of the fæces and urine are also determined. Then the proportion of food digested is regarded as the difference between the total nutrients of the diet, and those ejected in the excreta. Certain factors are assumed for the digestibility of the nourishing bodies in the milk or other extraneous articles, an allowance is made for these, and the digestibility of the bread alone is thus estimated. The methods of arriving at the amount of these and other allowances which must be made, together with the precautions necessary in order to ensure accuracy, cannot be discussed here, but are dealt with fully in the various original reports of these investigations. The principle of these tests can be made quite clear by an illustration, which is taken from a series in which the subject was fed on bread and milk only. Taking the protein figures they are:—

Food Consumed—Bread 67.9 grams + milk 66.2 grams = 134.1 grams.

Excreta—11.3 grams less from milk 2.0 grams = 9.3 grams, being estimated excreta from bread.

Total Amount Digested, being consumed less excreted, 134.1 — 11.3 = 122.8 grams.

Milk, Digestible Nutrients of, being consumed less excreted, 66.2 — 2.0 = 64.2 grams.

Bread, Digestible Nutrients of, being total amount digested less digestible nutrients of milk, 122.8 — 64.2 = 58.6 grams.

This subject, therefore, out of 67.9 grams of bread protein, digested 58.6 grams, or 86.3 per cent. of the bread protein consumed. In one such test carried out on three subjects the average result was that the following amounts of proteins consumed, were digested in the case of breads made from three grades of flour all from the same hard spring wheat:—

Patent Flour (about 70 per cent extraction)	85.3 per cent.
Intermediate Flour (about 85 per cent. extraction) ..	80.4 „ „
Whole Wheat Flour (100 per cent. extraction)	77.6 „ „

The following are the percentages respectively of total protein contained in each flour, and of protein actually digested and assimilated:

	TOTAL.	DIGESTED.
Patent Flour	13.14	11.2
Intermediate Flour	13.44	10.8
Whole Wheat Flour	13.86	10.7

In this series of tests therefore, while the protein increased with the length of extraction, the digestibility simultaneously decreased. In consequence the whiter the flour, the more available and digestible protein it contains.

Investigations on these lines have been made by Atwater, Woods and Snyder by direction of the United States Department of Agriculture, by Wood of the University of Cambridge, and by a committee of the Royal Society of England, which, during the period of the late war, issued two reports, one completed in December, 1916, and the other in March, 1918.

The whole of the results obtained by the two methods, and in all the investigations referred to, agree in demonstrating the fundamental fact that in matters of protein nutriment and production of energy, the longer the extraction of flour from the same wheat, the less nutritive is the bread, weight for weight.

535. Deficiency Diets.—The exigencies of the recent great war have caused all the nations participating to consider most carefully the problem of how to utilise to the best advantage limited and even deficient supplies of food. In the case of bread this becomes a matter of the greatest importance, since although weight for weight white bread is the more nutritious, yet evidently considerably more longer extraction breads can be made from the same amount of wheat. It is a matter of general scientific agreement that say 100 lbs. of whole meal bread yields a greater total amount of digestible nutriment than 70 lbs. of white bread. As a war or famine measure therefore, a longer flour extraction may be scientifically justified. Under more normal conditions, the consuming public elect to eat the more nutritive white bread and to utilise the bran, etc., for animal feeding purposes.

536. Mineral Nutritive Value.—This section of the subject has not been worked out with anything like the completeness that has been attained with the organic constituents of flour. Even in whole wheat the ash is not very high, the principal constituents being phosphoric acid and potash. As stated in Chapter V., the potash and lime are proportionately more in the fine flour than in the wheat; so also are the silica and ferric oxide. Even in the flour, the lime is very little, amounting only to 5.59 per cent. of the total ash, which in itself is very small.

Hutchison (*Food and Dietetics,* 1900, Chapter XVI.) discusses the mineral requirements of the body somewhat fully. He finds that the amount of mineral matters present in an ordinary mixed diet is more than sufficient for all the needs of the body, and that amount he fixes at about 20 grams per day. As to the form in which they enter into an ordinary diet, most of them are in a state of organic combination, such as calcium and phosphorus in milk. "It would appear that such organic mineral compounds are of special value in nutrition. It cannot be maintained, however, that it is *only* in such forms that mineral matter can find access to the blood. Experiment has shown that even such a substance as carbonate of lime is absorbed to some extent." From analyses of human milk, it would appear that an infant requires about 0.33 gram of lime daily: the adult requires less, because of the cessation of the growth of the bones. In the case of pregnant women, the requirements of the fœtus in the way of bone formation increase the demand for lime. A litre of milk, whether whole or skimmed, contains about 1.5 grams of lime, or 0.86 gram per pint. Hutchison regards phosphorus as a most important building material of the body, being found in cell nuclei and in abundance in bones and nerve tissue. It is therefore of great importance during the development of young animals. Phosphorus is present to a much greater extent in meats than in vegetable products; among the latter, haricot beans contain a very high proportion. "The phosphorus contained in foods is for the most part present in an organic form of combination . . . but in part also in an inorganic form as phosphates of the alkalies or earths. There is reason to believe that the organic forms are the more valuable for contributing to the growth and repair of tissue. Examples of these are the chemical substances nuclein, lecithin, glycerophosphoric acid, and phospho-carnic acid, all of which are probably valuable dietetic sources of the element. The foods richest in these are such articles as yolk of egg . . . and the germ of wheat. It is doubtful, on the other hand, whether the inorganic compounds containing phosphorus are of much value in the body . . . One can, therefore, hardly approve of the addition to the diet of phosphates in their inorganic form . . . The recommendation of such preparations is based upon the groundless assumption that an ordinary mixed diet is too poor in phosphorus to be able adequately to supply our need of that substance. It may be remarked in this connection that we know of no diseased condition which can be clearly traced to a deficiency of phosphorus in the diet. This is true, indeed, not of phosphorus alone, but of all the other mineral ingredients of the diet with the exception of iron, and possibly also of calcium. A deficiency of iron in the food may, as already remarked, lead to the development of anæmia, and too little lime in the food may cause the bones of children to become soft; but with these rather doubtful exceptions it may be safely assumed that an ordinary diet will amply provide for all the mineral matter we require." Hutchison further remarked that "of the comparatively small amount of mineral matter met with in bread, one-fourth is excreted unabsorbed. Seeing that this is the case, it is surely futile to recommend the use of bread containing a larger amount of mineral constituents."

Brunton and Tunnicliffe regard brown bread as being preferable to white where mineral ingredients and *especially lime salts* are deficient in other articles of food. As wheat is one of those articles in which lime is very deficient, it is difficult to see where in any case bread, whether brown or white, can very materially help as a lime food.

537. Importance of the Mineral Constituents of Foods, Ingle.—A paper on this subject was read at the Leeds Congress of the Royal Institute of Public Health in 1909. From the analogy of milk, Ingle regards the most suitable proportions of lime and phosphoric acid (P_2O_5) in food as being about 0.87 of lime to 1 of phosphoric acid. In support of this view he cites the authority of Weiske, by whom it has been shown that rabbits fed on oats alone developed thin, fragile skeletons, while similar animals fed upon oats and meadow-hay produced normal bones; moreover, that the addition of sodium dihydrogen phosphate to the diet intensified the bad effect upon bone development, while the addition of calcium carbonate to a diet of oats only, greatly improved the development of bone. Now oats contain about seven times as much phosphoric acid as lime, while meadow-hay contains 2.5 times as much lime as phosphoric acid. The writer points out that in seeds generally, among which wheat is included, there is this injurious excess of phosphoric acid, and although in wheat there is between three and four times as much magnesia as lime, yet for bone formation magnesia can only to a limited extent replace lime, for in the ash of bone only about 1 per cent. of magnesium phosphate is usually found, as compared with from 84 to 87 per cent. of calcium phosphate.

The writer then proceeds to express himself very strongly as to the merits, or rather demerits, of bran in the following terms:—"Allusion may here be made to what the writer believes to be a widespread fallacy—the impression that bran is well adapted to promote bone formation and nutrition. Bran is rich in ash, but contains an overwhelming excess of phosphorous pentoxide over lime—in some samples the writer found the ratio to be as high as 1:0.055—and, according to the views here given, should be extremely unsuited to bone nutrition. This is indeed the case, for a disease of the bones of horses, known as 'millers' horse rickets' or 'bran rachitis,' is known to be produced by the excessive use of bran as food." He regards bone diseases, *e.g.*, rickets, as being probably associated with the use of a diet containing a preponderance of phosphoric acid over lime, and suggests as a remedy for deficiencies in mineral constituents of food their artificial addition in the form of inorganic compounds. Thus in the preparation of "humanised" milk from cows' milk, he recommends the addition of finely divided calcium carbonate. Ingle regards the preponderance of phosphoric acid rather than the deficiency of lime in cows' milk as being the cause which renders it more liable than human milk to induce malnutrition of bone in infants. The same preponderance of phosphoric acid leads him to regard wheat, flour, and bread, as not presenting the most favourable conditions for bone development. He recognises, however, that cereal grains and their products form a large proportion of human diet without ill effects, and for adults at least the excess of phosphoric acid is not injurious. He regards this as being possibly due to different requirements in man to other animals, and also to the fact that the phosphoric acid of the ash does not all exist in the grain as such, but is largely derived from organic phosphorus combinations as lecithin. Such phosphorus is possibly not converted into phosphoric acid in the body, and would therefore not act harmfully in bone nutrition, the really important ratio being that of lime to phosphorus pentoxide existing as acid in the food. (*Jour. Royal Institute of Public Health*, 1909, XVII., 736.)

538. Nutritive Value of Phosphates, Holsti.—Almost concurrently with Ingle, Holsti points out that experiments on animals in which the question has been investigated whether the body can obtain its phosphorus from inorganic sources, have not in the hands of various investigators yielded concordant results. In the present experiments described by him, in which organic and inorganic phosphorus were determined in the food and excretions of man, the result obtained is that it is possible to supply the necessary phosphorus in large measure from inorganic phosphates. (*Skand. Arch. Physiol.*, 1909, **23**, 143.)

539. Conclusions.—The balance of evidence is in favour of the view that ordinary diet contains a more than sufficient quantity of phosphorus, and therefore that the amount present in bread is of but little or no importance. Ingle goes further and regards the preponderance of phosphoric acid over lime as positively detrimental. There is considerable divergence of opinion as to the nutritive value of phosphates. Thus Hutchison looks upon them with doubt, but admits that in certain cases inorganic salts such as calcium carbonate undergo some degree of absorption. Ingle evidently agrees with Wieske that oats is a very bad bone-forming food, and similarly condemns wheat; they both regard the addition of calcium carbonate as a definite bone-food. Ingle rather queries whether the phosphorus of such organic compounds as lecithin is even converted into phosphoric acid in the body. If not, it evidently cannot act as a bone nutrient, for which the inorganic calcium phosphate is required. Holsti, as a result of direct experiment, regards inorganic phosphates as capable of supplying a large measure of the necessary phosphorus of the body. The authors suggest as a probable solution of the problem that the human body requires phosphorus in two distinct forms: (1) as organic compounds for the building up of brain and nerve tissue, which contain such compounds of phosphorus in large quantity; (2) as inorganic salts for the building up of bone tissue, which consists largely of calcium phosphate. Lecithin and such substances will naturally go to the construction of nerve tissue, and inorganic phosphates to bone-formation. When either organic or inorganic compounds of phosphorus are deficient, the human body is probably able to utilise for both purposes phosphorus compounds of either type.

In the case of lime, the position is different. Brunton and Tunnicliffe, Ingle, and to a lesser degree Hutchison, regard lime-starvation as being within the bounds of possibility. Ingle adduces very strong evidence that such deficiency may be made up by the use of lime carbonate as a part of the food. Unfortunately, wheat in any of its forms contains very little lime. In particular, the use of bran as a food is strongly contra-indicated, as it may very possibly be the cause of actual injury to bone formation and nutrition.

540. Comparative Bacteriological Purity.—Owing to causes over which the miller has no control some wheats reach him in a very dirty condition. As a remedy most complete installations of wheat-cleaning machinery form part of the equipment of every modern mill. The wheat is dry-scoured, washed most thoroughly and dried; but it is impossible, owing largely to the crease in the grain, to thus ensure its absolute freedom from external impurity. Such impurity is naturally associated with the bran, and during the operations of milling remains in most part attached thereto. A portion is rubbed off by the more severe reductions into the lower grade flours, but the higher grade flours are practically free from any contamination that may exist on the outer side of the bran. Among such impurities are found large numbers of bacteria, and some of these may be very objectionable, and in rare cases even dangerous in their nature. In consequence, whole-meal and the darker low-grade flours are much more liable to bacterial contamination than those of the patent types. The results of these conditions have long been familiar to the baker, who knows that the darker flours are much more likely to produce sour bread. In the following experiment a first patent flour and a dark or low-grade flour from the same class of wheat were taken, and fermented and baken in precisely the same way. Loaves were baked from each after 3½ hours and 9 hours' fermentation respectively. They yielded on analysis the following amounts of acidity per cent.:—

	White Bread.	Dark Bread.
After 3½ hours	0.477	1.140
After 9 hours	0.491	1.300

The less fermented loaves had the following characteristics: *White,* sweet in smell and taste; *Dark,* characteristic odour of bread from low-grade flours, but perfectly sweet in taste and smell. The 9-hour loaves had shown some further change. The *White* was darker in colour, had an incipient sour smell, but no sour taste. The *Dark* had the colour changed to dark reddish brown, sour smell, and unpleasant taste, rather of decomposition than acidity.

Kenwood, in conjunction with one of the authors, has on several occasions made comparative bacteriological examinations of wheat and flours.

The following are the results of one such test. Three flours were taken:—

A. Highest grade patent flour.
B. Lower grade flour.
C. Stone-milled flour.

These were similarly treated, and preparations of each were incubated for bacteria on gelatin plates. At the end of 42 hours the following observations were made:—

A. No growth.
B. Four large colonies and over 100 small ones (non-liquefying).
C. Twenty well-marked colonies, and many organisms (which could not be enumerated), had liquefied one-third of the gelatin.

At the end of 72 hours:—

A. One non-liquefying colony.
B. One liquefying colony, and quite 200 small non-liquefying ones.
C. The gelatin was entirely liquefied.

In another test, experiments were made with a wheat containing *B. coli communis.* The wheat itself yielded twelve colonies of *coli.* Samples of highest grade flour, medium grade flour, and bran from this wheat were examined. Repeated tests on the highest grade flour gave no growths of *coli.* In each of separate tests, two colonies of *coli* were obtained from the medium grade flour. The bran yielded a growth of *coli* which covered the gelatin plate.

High grade flours are practically sterile, and bacteriologically cleaner than medium and low-grade flours, and far cleaner than whole-meals. Such organisms as *B. coli communis,* if present in the wheat, are absent from the highest grade flour, present in small quantity in that of medium grade, and abundant in whole-meal. The same differentiation would no doubt apply to other organisms having the same habitat as *B. coli communis,* if they happened to be present.

541. Attractiveness and Palatability.—These two factors have immense weight in deciding what shall be the leading type of bread consumed by the community. They are also of the utmost importance. As long ago as 1857, Lawes and Gilbert recognised that: "It is also well-known that the poorer classes almost invariably prefer the whiter bread, and among some of those who work the hardest and who consequently soonest appreciate a difference in nutritive quality (navvies, for example), it is distinctly stated that their preference for the whiter bread is founded on the fact that the browner passes through them too rapidly; consequently, before their systems have extracted from it as much nutritious matter as it ought to yield them." The fact of this preference also applies to such districts as some parts of Scotland, where very little meat is eaten, and also to even the poorest parts of Ireland. In both cases a very white bread is demanded. But not only does this taste exist among the poorer and harder physically worked classes, it is also general throughout the whole community. As recently stated in the daily press, "there is a popular craving for white bread." If asked the reason why they preferred a white loaf, the probable answer of the people would be: "We prefer a white loaf because it is more dainty in appearance, and because whiteness is instinctively associated with cleanliness. A muddy-looking loaf may be quite clean, but does not so thoroughly convey that impression as a creamy white one. Further, the white loaf has a nicer taste." Snyder puts it on record that during the severe monotony of his digestion tests, in which the subjects were restricted to a diet of bread and milk only, they keenly preferred the white bread to the brown. In other words, the general taste regards the white loaf as the more attractive and palatable. Authorities on diet regard both of these as being of importance. Tunnicliffe writes: "Recent research has distinctly taught us that, from the point of view of its nutritive value, great importance attaches to the appetising appearance of food." (*Blue Book on the Use of Preservatives in Food,* p. xxxi.). Hutchison is also strongly in favour of regarding the flavour of food as one of the essential characteristics of the diet. He sums up his position by the remark: "To persons of jaded appetite, however, and to invalids and convalescents, the flavouring agents of the food are very powerful aids to digestion, and no adjustment of the diet in such cases can be regarded as satisfactory which leaves this consideration out of account." (*Food and Dietetics,* p. 274.) On general dietary principles, therefore, there is a scientific justification for the popular preference.

542. Complementary Foods to Bread.—In view of the fact that bread is naturally deficient in protein and fat, amongst organic nutrients, and in lime among mineral matters, it may be well to indicate those articles of food which are appropriately regarded as complementary or supplementary to bread itself. Bread is very rarely eaten alone; meat and cheese supply its deficiency in protein; leguminous vegetables such as haricot beans have the same effect. Fat is almost universally added to bread in the form of butter. Dietetically, jam or other sweets cannot be regarded as an efficient substitute for butter, margarine, or dripping. In view of the deficiency in lime, milk is strongly indicated as an accompaniment to bread. Here custom anticipates science by causing bread-and-milk to occupy a prominent position in the dietary of children. May not the reputation of "the halesome parritch" as a bone-food be largely due to the milk consumed therewith rather than to the oats from which it is prepared?

In improved methods of bread-making, both fat and milk are at times employed. Both are good; but the latter especially, whether with or without the cream, serves to increase the lime content of the bread. If bread be made entirely with skimmed milk, a half kilo (approximately 1 lb.) will contain about 0.3 gram of lime, or roughly the daily amount required by an infant. Such bread would be far better adapted to the requirements of pregnant women than that from whole-meal. Judging by analogy, the addition of a small proportion of an appropriate lime salt would be a further advantage. Such salt might possibly be the carbonate, which would be changed into the chloride by the hydrochloric acid of the gastric juice; or it might be added direct as the chloride, in which case it would partly replace sodium chloride or common salt.

In some districts a portion of the liquor used in making dough consists of lime-water; the lime of this is converted into the carbonate, by the carbon-dioxide gas evolved during fermentation. The use of hard waters for bread-making, *i.e.,* those containing calcium carbonate or sulphate, also adds to the lime content of the bread. Hard water is itself an important source of lime in the daily income of food, and may under certain circumstances contribute that substance in excess.

543. Summary.—The foregoing data justify the following conclusions.

Taking breads as supplied by the baker, white bread is weight for weight more nutritious than whole-meal or ordinary brown breads. The average best white bread is more nutritious than the second quality or that made from the darker or low-grade flours.

When from any kind of wheat, standard patent (which is practically the whole of the flour of the wheat) is compared with "entire-wheat," and graham flour from the same wheat, the white flour yields more nutriment and energy than either of the others.

The addition of finely divided bran to white flour lowers the nutritive value of the mixture.

The addition of germ in excess of that normally present in wheat, increases the nutritive value of the bread.

Wheat and all kinds of flour therefrom are comparatively poor in mineral constituents. The phosphoric acid is largely in excess of the lime. No diseased condition is known, which can be clearly traced to a deficiency of phosphorus in the diet. All breads contain more phosphates than are absorbed by the human digestive system. All wheat preparations are deficient in lime. Bran is detrimental to healthy bone-formation.

The human body requires phosphorus in two distinct forms, as organic compounds for the building up of brain and other phosphoric tissues, and as inorganic salts for the building up of bone tissue which consists largely of calcium phosphate. In case of deficiency of compounds of either type, the body is probably able to utilise for both purposes phosphorus compounds of either variety.

Wheat is liable to bacteriological contamination, which conceivably may be of objectionable or even dangerous character. The whole-meal will obviously contain the same bacteria as the wheat. The low-grade flours contain less bacteria than the wheat, but some are still present. The high-grade or patent flour is practically bacteriologically clean, even when made from a contaminated wheat.

The bakers' best white bread is more attractive and palatable than darker coloured or whole-meal breads made from plain flour or meal only. These in themselves are valuable nutritive assets.

The nutritive deficiencies of bread are best remedied by the addition of butter, milk, cheese, meat, and leguminous vegetables to the diet. These supply respectively fat, lime salts, and protein. Hard water, or appropriate lime salts added direct, would probably help in correcting the deficiency of lime in wheat.

No case has been made out for recommending the use of whole-meal bread by growing children or pregnant or nursing women.

544. Vitamines, or Accessory Food Factors.—In the last edition of this work reference was made (page 558) to certain experiments of Hopkins of Cambridge from which he drew the conclusion that young children would grow and thrive much better on a dietary largely consisting of bread made from 80 per cent. extraction flour than on a dietary containing a similar proportion of white bread. This view was based, not on the superior nutritive value and digestibility in the ordinary sense, but on his opinion that the longer extraction flour contains "certain at present unrecognised food substances, perhaps in very minute quantities, whose presence allows our systems to make full use of the tissue building elements of the grain." Since that date much important work has been done in this direction. In the briefest possible manner, the present day knowledge and conclusions are here summarised. The theory of those physiologists who have given this subject their attention is that there exists a class of substances provisionally termed "vitamines," which exercise most important functions in the process of nutrition, and yet "are present in articles of food in quantities far too small to constitute any appreciable contribution to the energy supply of the body." The first step in this research was the discovery that if minute quantities of certain constituents are removed from a food it, the food, wholly fails to support nutrition. Further, if these substances are again returned to the food, health is once more restored. The best known of these cases is that of the rice-eating nations, with whom completely white polished rice induces a disease known as beri-beri; while if the husk only is removed, and the skin of the grain and the germ retained, rice in this condition not only prevents the disease, but acts as a cure in the case of those suffering from this complaint. The following "vitamines" have been more or less separated and identified:—

1. *Fat-Soluble A.* This substance is probably produced by plants during growth, and is found both in the green leaves and in the germ of many seeds. Animals do not seem to possess the power of synthesising this body; but store it up in relatively considerable quantities from their vegetable food. As a result butter and egg-yolk are comparatively rich in this substance.

It is soluble in reagents which dissolve fats, such as ether, and generally also in fats themselves. Heat slowly destroys it, and four hours' exposure to a temperature of 100° C. serves to make butter fat inactive in this direction.

Fat-soluble A is essentially an agent for developing growth. If young animals are deprived of it in their food, there are no immediate results, as a reserve stock is carried in the body. As soon, however, as this is exhausted, growth ceases and the animals become extremely susceptible to invasions of disease of a bacterial nature, especially tuberculosis. Adult animals tolerate a deficiency of this substance for some time, but ultimately the general state of health is seriously lowered, and the capacity for resisting disease inroads disappears. In cases where deficiency conditions have been set up, health to a greater or less extent may be restored by the use of food containing this body. A shortage of Fat-soluble A as distinct from its absence results in lowered vitality and growing powers.

DISTRIBUTION IN FOOD STUFFS.

The following table shows how both Fat-soluble A and another body, Water-soluble B, are distributed among articles of food. The comparative quantities are indicated by the terms, Large, Moderate, Small, Absent.

	Fat-soluble A.	Water-soluble B.
Fats—		
Butter, Cream	Large, moderate.	Absent.
Mutton and Beef Fat	Moderate.	
Lard	Absent.	
Most Vegetable Oils and Fats	Absent.	
Margarine, animal origin (except lard)	Moderate.	
,, (vegetable origin and lard)	Absent.	
Cod-liver Oil	Large.	Absent.
Meats and Fish—		
Lean Beef or Mutton	Inconclusive result.	Small.
Liver, Kidneys, Heart	Moderate.	Moderate to small.
Lean Fish (as cod, haddock)	Absent.	Very slight, if any.
Fat ,, (as herring, salmon)	Moderate.	,, ,, ,,
Wheat—		
Germ	Moderate.	Large.
Endosperm	Absent.	Absent.
Bran	Inconclusive result.	Moderate.
Whole Meal Bread	Small.	
White Bread	Absent.	
Vegetables—		
Cabbage, Lettuce, Spinach	Moderate.	Small.
Miscellaneous—		
Nuts (walnuts and fatty nuts)	Small.	Moderate.
Milk (cows' whole, raw)	Moderate.	Small.
" (skim)	Absent.	Small.
Cheese (whole milk)	Moderate.	
,, (skim milk)	Absent.	
Whole Eggs (fresh or dried)	Moderate.	Large.
Egg Yolk	Large.	Large.
Egg White	Absent.	
Yeast	—	Large.
,, Extract	—	Large.
Meat Extract (commercial)	Absent.	Absent.

Water-Soluble B.—This is a substance of vegetable and animal origin, as shown by its principal sources, which are seed embryos or germs, and also yeast and egg yolk. It differs from Fat-soluble A in that it is insoluble in ether, and is soluble in water. Water-soluble B is necessary to promote a satisfactory growth in young animals, and also it is the special factor in preventing the occurrence of beri-beri and neuritic diseases in man and animals. So far as the action of heat is concerned, during the baking of bread the temperature does not rise sufficiently high to cause any serious diminution in the activity of this substance.

Water-soluble B is also necessary to the growth of young animals; in addition it is requisite for adults. In both cases, with its deprivation, there is a fall in body weight, with a fatal termination. Animals do not seem to build up any reserve of this substance, so that as soon as the supply ceases, the ill effects are quickly visible. Certain specific diseases, of which beri-beri is an example, follow from the absence or markedly insufficient supply of Water-soluble B. "Beri-beri is rare though not unknown where white bread is eaten, because the consumption of this type of cereal food is usually accompanied by a sufficiency of other food-stuffs containing the essential principle."

Deficiency Diets.—The distribution of vitamines, or accessory food-factors in an ordinary mixed dietary is so wide that but little or no importance attaches to their comparative absence from white bread. When, however, famine conditions prevail, as in times of war, the range of vitamine containing substances may become dangerously narrow and consequently the conservation of their every source is simply a provision of safety. Notwithstanding its various disadvantages, actual necessity may then make the use of long extraction flours or even whole-meal bread imperative as a measure of getting the greatest possible amount of direct nutriment and accessory food-factors from a given weight of wheat.

The authors are indebted for the summarisation of much of the above information to a *Report on Vitamines, by the Medical Research Committee, published by His Majesty's Stationery Office,* to which the reader is referred for a more detailed account of the subject.

CHAPTER XVIII.

BAKEHOUSE DESIGN.

545. Selection of Site.—In determining the site for a bakery, one of the first matters to engage attention should be to select a locality suitable from a commercial point of view. A practical baker would at once satisfy himself whether or not a neighbourhood looked as though it were growing and improving, or the reverse; whether it was already over-stocked with bakeries, or whether there were still openings; whether full prices were being obtained, or whether the locality was an undercutting one. The nature of the roads, whether hilly or level, and all items bearing on the cost of getting flour into the bakehouse and of delivering bread from the bakehouse, would be duly noted, and the proper weight given to them in forming a judgment as to the suitability of the spot. All these may fairly be termed commercial aspects of the question; but beyond these there are considerations which are more intimately associated with the practical necessities of bread-making.

Among these a leading place must be given to the degree of fresh air obtainable, and generally hygienic surroundings. The situations best adapted for *selling* bread are not necessarily those also best suited for making the same. A good shop will be naturally where rents rule high and property is valuable; as a result, baking operations are of necessity frequently conducted in a far too limited space for the most efficient and healthy working. In consequence, the system of having bakeries in more thinly populated districts, where land is less valuable and a building capacious enough to accommodate modern labour-saving plant can be erected, and using the shops as selling places only, is being more and more adopted. With large firms having abundance of capital this is comparatively easily managed, but in the case of smaller concerns greater difficulty exists. But except where really good bakehouses are actually in use, it is a matter for serious consideration whether the bakehouse should not be altogether distinct from the shop. However crowded a locality, there may generally be found at a not unworkable distance a site where a bakehouse, pure and simple, may be erected. The bread rounds may be served direct from where the bread is baked, and only those goods brought to the shop which are requisite for a counter trade. The difficulty is that this means two places to be supervised instead of one; but even when under the same roof the bakehouse is absolutely distinct from the shop, and the hours of work are by no means simultaneous. By the use of the telephone, communication between the two becomes such that orders and messages may be readily transmitted. Granted that arrangements of this kind mean extra expense, still in the matter of hygienic requirements the public is master, and will in the long run insist, in no uncertain manner, upon bread-making being carried on under satisfactory sanitary conditions, and the trader who keeps ahead of time, reaps a handsome reward for his enterprise.

There is no doubt that a bakery on the ground flour has a far better chance than one situated underground. No one more thoroughly recognises than the authors the difficulties, in many cases, of finding in old bakers' shops accommodation for the bakehouse other than below the shop, and also that many bakeries exist below the street level, and are yet clean and healthy; but it is in spite of their situation, and not because of it, that they are thus clean. To keep them so requires far more effort and attention than when they are above ground. When a new building is being erected, it may frequently be an advantage to have a sloping site, thus permitting two approaches on different floor levels; this, however, is not often obtainable. It may further mean that the district is hilly and, so, difficult for the delivery of bread. The site should be dry and well drained; also well ventilated, but sheltered as far as possible from exposure to cold winds, especially on the north and east sides. The top of a hill has advantage over the bottom for the delivery of bread, inasmuch as the full vans have a downhill journey.

546. Requirements in the Building.—These will be best grouped under various headings, each of which will be considered in turn.

The following general conditions should, however, be borne in mind in connection with all that follows, and especially in reference to the description of typical bakehouses illustrated.

Floors.—Many different types of floors have been tried, but it may be accepted that the best plan is to select some type of flagged or tiled floor. Owing to heavy traffic certain parts of the floors wear more than others, and no homogeneous flooring material that will lend itself to efficient repair in selected places has yet stood the test of hard work. The heat in bakehouses, together with the short time during which repair work can be permitted, constitute the great difficulties in this respect. It is obvious, therefore that stone flagging, artificial stone slabs, tiles or hard bricks, which can all be readily removed in worn places, and relaid efficiently without interruption to work or fear of break up, form the ideal materials for a bakehouse floor. In certain factories where the wear is very heavy, floors have been introduced with a surface of cast-iron plates with hexagonal honeycomb perforations. The plates are laid on cement and the holes filled with cement to the upper surface.

Walls and Ceiling.—These should preferably be of washable material (glazed bricks, parian cement, tiles or the like); all piers should be outside the building; only plain surfaces should be used inside and no sharp corners should be employed. Thus, the walls should join one another, the ceiling or the floor, by a rounded corner with a radius of at least one inch. Where considerations of expense make such perfection impossible, plain brickwork walls, kept well lime-washed, are the only alternative which can be recommended. Upper floors should preferably be ferro-concrete with girders and joists cased in cement, again avoiding all sharp corners.

Windows and Doors should be placed to avoid draughts as far as possible; they should be well fitting, especially on walls exposed to strong winds. Sloping window sills are advisable, as they prevent the accumulation of dust and cannot be used for the storage of odds and ends, which are not only objectionable, but are often the cause of broken windows.

Chimneys should never be less than 9 in. by 9 in., measured internally, and should run up outside main walls to above the ridge of roof or highest building adjoining. Avoid cowls and horizontal connections, and never put a round chimney pot on a square chimney unless its diameter equals the diagonal of the square chimney section. One chimney to take a number of ovens is quite satisfactory if large enough and properly arranged, but often a number of smaller ones is less costly.

Roofs should exclude draughts as well as wet. If fitted with ventilators, these should have means for control. Avoid too much glass roofing over the actual doughing room and bakery (in such cases where there is no floor over): it is too hot in the summer and too cold in the winter.

General.—Avoid fixtures as far as possible; let all tables, troughs, bread racks and fittings be on casters or wheels to facilitate transportation and cleanliness.

Motive Power.—Gas engines are shown in some of the plans on account of their being the most usually available source of power, and also the heaviest and most difficult to accommodate, thus showing that lighter or smaller prime-movers will have ample room. Space and often expense will of course be saved by adopting electric motors where current is available. The subject of motive power is fully dealt with in paragraphs 562 to 564.

547. Working Requirements—Compactness.—In natural sequence there next come forward for consideration the requirements of the baker in using the building, as these must vitally affect the design. Among such one of the first to occur is that of compactness: bakeries are not wanted to be long and straggling, or with the work going on simultaneously in more than one place. There is otherwise the inevitable loss of time resulting from inadequate supervision, and also that necessarily following from ovens, machinery, tables, etc., being too far away from each other, and what is more important the difficulty of ensuring the correct temperature and atmosphere. In the next place, matters must be so arranged that all approaches and exits are under control, so that the delivery of flour and raw material, and also the packing up and dispatch of bread and finished goods, may be easily and efficiently checked. Where at all practicable, all means of egress and ingress should be through the one main entrance, or, if through different entrances, the whole of these should be under control from the office. In the case of a retail trade, there must be ready means of delivering goods from the bakehouse to the shop. This necessitates, in the case of bakery and shop being on the same level, a direct passage from one to the other. With a bakery either under or over the shop level, the best plan is a simply constructed lift.

548. Ventilation.—As already explained, efficient ventilation is compulsory under the Factory Act, but apart from that the necessities of the case would lead every baker to ensure his ventilation being as perfect as possible. With all hot work the comfort and health of the operatives require abundance of fresh and pure air. The ventilation of a bakery is fraught with some difficulty, as it is extremely important that there be no draughts nor sudden chills through the admission of large quantities of

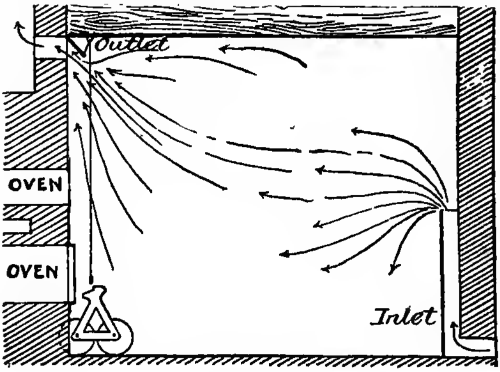


Fig. 34.—Diagram Showing Ventilating Air-Currents.

cold air in a short space of time. Ventilation is usually effected by what are known as convection currents, the scientific explanation of which has been given in the introductory chapter. Briefly, air expands as it gets hot, and consequently is lighter, bulk for bulk, than when cold. As a result hot (light) air is displaced by cold (heavy) air, and it may be said that hot air floats upwards, and cold descends to take its place. From this it follows that in rooms where gas is burning or where there is any source of heat, the upper part of the room is distinctly the hotter. If air-flues are led upwards from the upper portion of a room used as a bakery, the hot air will escape from these, while cold air will stream in to take its place at the lower levels if suitable openings are provided. This effect is easily studied in the accompanying figure, No. 34. Immediately over the ovens is an uptake to which a sliding door is attached; this is exceedingly simple, and is readily worked by a cord from the floor level. At the sides in various places are inlet pipes; the tops of these are so placed that the cold air cannot strike directly on troughs or other vessels containing ferments, sponges, or doughs.

A useful form of ventilating flue is constructed from a compound chimney pipe such as shown in sketch, Fig. 35. This pipe is made of earthenware, in lengths of from 12 in. to 18 in., with spigot and faucet joints like those of an ordinary drain pipe. But on one side of the flue pipe is formed a chamber; this separate chamber or flue is the air flue. The heat of the chimney portion warms the air flue, and so creates a powerful draught through it. Oven chimneys may, as shown, be constructed of such piping; so also in underground bakehouses may the flues for fires in rooms above, the air flue being carried down into the bakery. Windows may be used for ventilating purposes, but it is then a good plan to place a board on the lower side, so as to cut off any direct indraught.

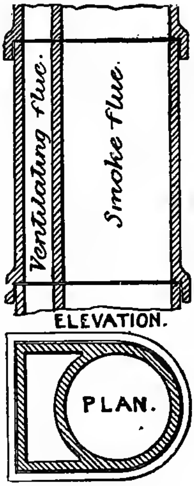


Fig. 35.—Ventilating Chimney Pipe.

549. Constancy of Temperature.—Sudden changes in temperature are of course largely produced by draughts, but also may be due to the construction and materials used in the actual building of the bakehouse. Lath and plaster are *not* the most suitable methods of building bakehouse walls. These should be constructed either of stone or brick of sufficient thickness, and if the latter be used a fairly solid brick is an advantage. Brickwork should be cemented on the surface, or other steps taken to ensure its being water-tight. The same reasons which militate against thin walls also apply to iron. For light sheds corrugated iron may do very well, but it is not the material for bakery construction. Its ready conductivity of heat causes the bakery to be extremely cold in winter and hot in summer. For the same reasons open iron roofs are to be condemned. To prevent fluctuations in temperature there is nothing so effective as having another room over your bakery, and the common practice of having the flour store above is more than justified by its influence in maintaining an equable temperature in the bakery itself. Suitable roofing is also important and should receive careful consideration. Slated roofs are not necessarily the best, but the builder, architect or engineer should be able to advise as to the best roofing to suit any given locality, if his attention be drawn to the need for roofing such as will be warm in winter and cool in summer. Special attention may be here called to suitable specialised roofing felts, which are not only excellent but durable and cheap. (See also paragraph 584.)

550. Arrangements for Ovens.—It may be taken as a cardinal principle of the authors that ovens should be fired from outside the portions of the building in which baking operations are carried on. In conjunction with this, one has of course to bear in mind the fact that internal firing, or firing in some other way from the front, is much preferred by some bakers; but such reasons as once existed for such preferences can hardly be said to apply today. Oven constructions are now available which enable any class of work to be perfectly carried on, and are yet arranged to be fired from outside the bakery proper. Supposed inapplicability of modern externally fired ovens for certain classes of work is more imaginary than real, and there are now ovens available which, fired from outside the bakery, do as good quality work as others with the fire manipulated within the bakehouse proper. This view leads the authors to suggest the provision in bakeries of a separate stokehole, with means of access from the bakery, and separate entrances for the bringing in of fuel and the carting away of ashes. Ovens may be built within the bakery itself, but where practicable the authors prefer to have them outside, with lean-to or other roof covering over the ovens themselves only. This separate building can then receive independent ventilation, so as to avoid undue heating by the oven of the bakery itself. Where there is a row of ovens, their faces and doors should be flush with, or form part of, one wall, and this wall should be carried of course right up to the ceiling. This should be done even if the ovens are within the main building, and have the upper rooms extending over them. Such a wall may also assist to bear the superincumbent weight, if desired to do so, but it is well so to arrange matters that independent pillars or columns are provided between each oven to carry the weight above. The general work may be faced up uniform with these, or the ovens may be slightly recessed, so as to give a somewhat improved architectural effect, but in either case ovens and buildings should be separate and distinct from each other.

The design of the bakehouse must depend somewhat on the nature of ovens selected. These resolve themselves, so far as British practice is concerned, into several types, of which the ordinary oven loaded with a peel (usually a rectangular chamber) and the drawplate oven, which is narrow and elongated, are the most frequent. The particular shape of this latter variety is determined by the width of plate over which men can set bread by hand, except for close-set bread and other varieties which lend themselves to the use of setters. This consideration practically limits the width of drawplates to six feet, which space can be readily spanned by reaching from either side.

551. Machinery.—The arrangements in this matter must depend largely on the space at command and its shape and other characteristics. The engine should have a separate room provided for it. This is not often a matter of great difficulty, because in even a small bakehouse the engine may be screened off with a glass and woodwork partition.

Naturally, in arranging machinery and the bakery generally, provision will be made for running materials about as little as possible. In Great Britain, flour store-rooms are generally at the top of the bakery, and the flour is at once raised there when brought into the building owing to the convenience of utilising the laws of gravity for the conveyance of the flour and dough to the lower floors. In countries with more severe climates, however, where extreme cold and heat is experienced, the flour is often stored in underground cellars to enable it to be kept at a uniform temperature. Elevators are then employed for conveying it to the top floor for distribution as before referred to.

552. Typical Bakery Designs.—Having dealt with general principles, an effort will next be made to show how these principles may be embodied in everyday work. For that purpose the following descriptions, illustrated by plates VII to IX are given. It must be remembered that these are not to be taken as complete working drawings; many little details of construction are omitted, because they do not affect the general principles of the design.

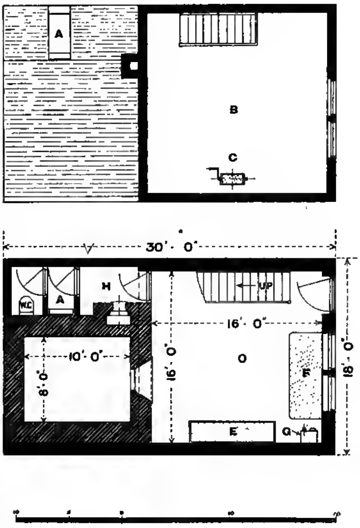
553. Single Peel Oven Bakehouse.—On Plate VII there is shown a small bakehouse fitted with one peel oven, which may be of the one-deck or two-deck type. The outside width is 18 ft. 6 in., windows all in front, and depth 30 ft. The choice as to which of the two types of ovens mentioned shall be decided upon, will be governed by consideration of size and nature of trade as well as cost; for guidance in this respect refer to paragraphs 597 *et seq.* dealing with ovens. The firing arrangement is at the side, giving a separate stokehole, fitted with coke bunker. The assumption is that the oven is not accessible at the back; in fact, that no facilities for either light or entrance are obtainable from anywhere but the front. Beyond showing a kneading trough and tempering tank (see paragraph 577) at one side, no attempt has been made to introduce fixtures and utensils; the places for the latter will suggest themselves to the baker in looking over the plan. The staircase leading to the flour store above is arranged so as not to interfere with the lighting of the bakehouse, and to enable the kneading trough to occupy a position in which it is not exposed to the draught from the entrance doorway. In the flour loft is shown in outline the position of a sifting machine (see paragraph 576), through which flour is intended to be delivered into the trough below. This machine is readily worked by hand, and should be considered indispensable as all flour bags contain foreign matter such as oddments of string, fluff, etc., which may easily escape the dough maker. The oven portion of the building is covered by a lean-to roof, one storey high, and raised and louvred portions should be fitted at the upper part of the roof to provide ventilation. The top of the oven is separated from the bakehouse by a brick wall, but is open to the stokehole, which is therefore also efficiently ventilated. A large amount of work could be easily done in a bakehouse of this type.

Assuming a two-deck oven, the lower chamber should preferably be reserved for bread and the upper for confectionery, and with a modern steampipe oven in which each chamber is fired independently of the other and capable of yielding a batch of 2 lb. crusty loaves per 1¼ hours, a trade of 30 to 35 sacks (280 lbs.) per week is possible. In addition to this a considerable output of confectionery and cake will be obtained by using the oven during the hours in which the bread baking is stopped. The introduction of proper drainage and sanitary appliances would render this bakehouse, small as it is, perfect, from a hygienic point of view—so perfect, at least, as hand-making appliances will permit.

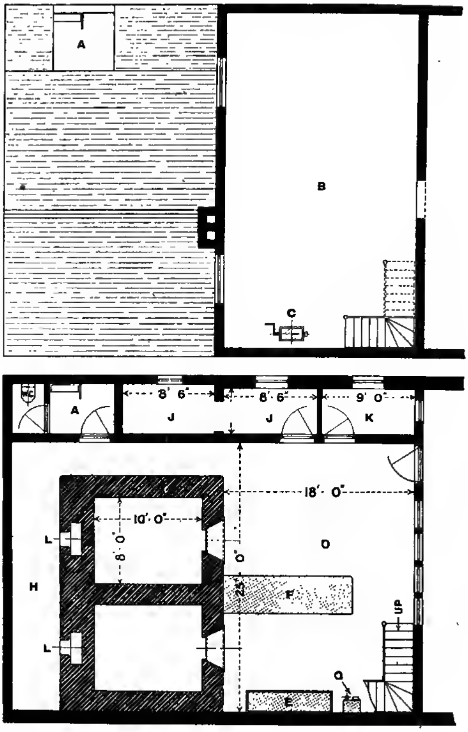
554. Bakehouse for Two Peel Ovens.—The next plan on the same Plate, VII, is one of a larger bakehouse, in which both front and side light is obtainable, although it will be seen the latter can be easily dispensed with. This bakery is shown fitted with two peel ovens, which again would preferably be two-deck. One of the upper ovens may be arranged as a steam-retaining sloped sole oven for glazed or Vienna bread. The suggestion here is that the ovens shall be fired at the back, and accordingly a stokehole extends the whole length of the back; opening from

PLATE VII. Plans of Bakehouses.

With One Peel Oven.



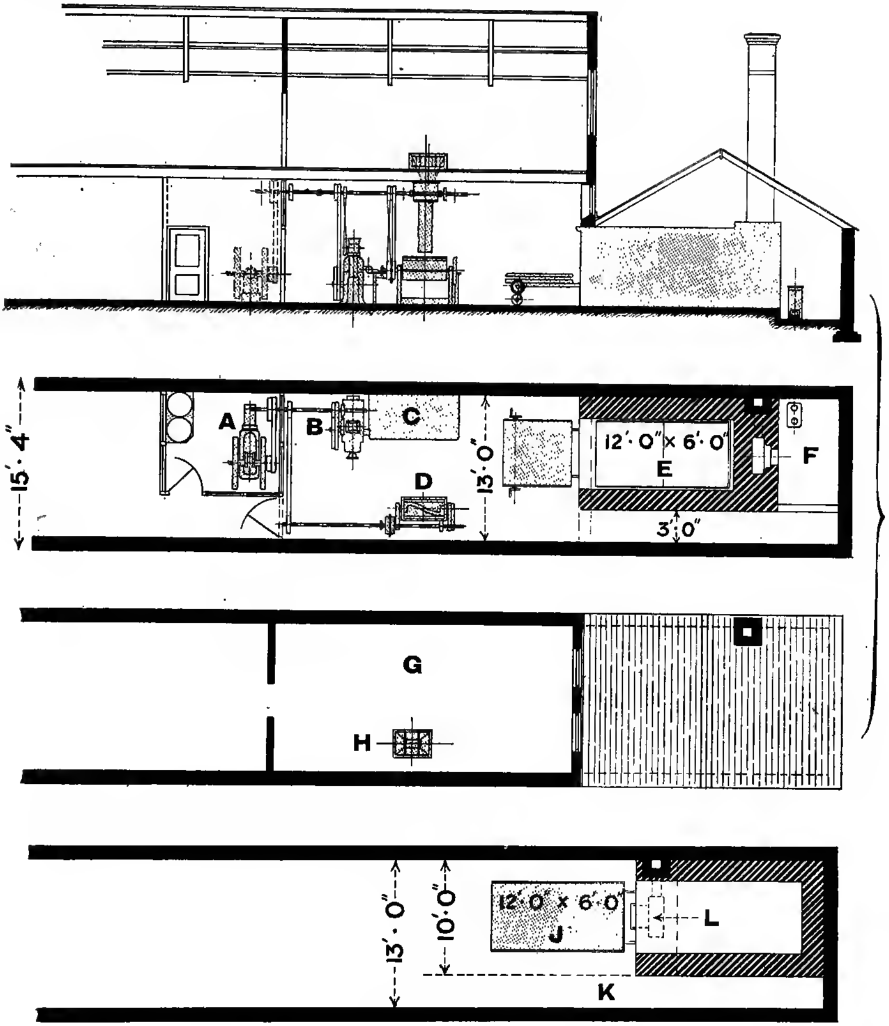
With Two Peel Ovens.



REFERENCES.

A. Open Yard.
B. Flour Store.
C. Sifter and Shoot.
D. Bakehouse.
E. Dough Trough.
F. Moulding Table.
G. Tempering Tank.
H. Stoke-hole.
J. Confectionery and Stores.
K. Office.
L. Furnaces.

PLATE VIII. Plans of Single Drawplate Oven Bakery.



REFERENCES.

A. Gas Engine.
B. Dough Divider.
C. Moulding Table.
E. "Single Blade" Kneading Machine.
F. Drawplate Oven.
D. Stoke-hole.
G. Flour Store.
H. Blending Hopper, Sifter and Shoot.
J. Drawplate.
K. Space for Dough Trucks and Proving Dough.
L. Front-fired Drawplate Oven.

the passage to the stokehole is a door leading to a small yard, in which are built a lavatory and men's offices. In order to protect workmen this passage is roofed over, but left open on side nearest the yard. The bakery has a table in the centre, while sufficient kneading troughs would find room against the walls. A sifting machine and tempering tank, as before described, are shown in a position to which the troughs may be in turn conveniently moved. All kneading troughs should be on casters to enable them to be readily moved to suit the work as also to enable thorough cleaning of floors, walls and corners. To the right hand of the bakery is a small office, and behind is a pastry-room. Over the bakery is the flour store, arranged as in the previous sketch. A bakehouse such as this would have capacity for a large trade, and with properly selected ovens there would be no difficulty in turning out a hundred sacks per week, and also the corresponding amount of small goods, confectionery, and cake. Of course, the amount of bakehouse space might in such a case be increased with advantage, or the space might be altered in shape to meet exigencies of site. The sketch is merely intended to indicate the minimum space required for the amount of work wanted. No provision has been made here for machinery, but such could easily be adopted if desired. Bread-rooms and other conveniences should be attached to the bakery front, or side opposite ovens.

555. Single Drawplate Oven Bakery.—Plate VIII shows plans of a bakehouse fitted with a split-type drawplate oven, Fig. 60, over which may also with advantage be built a peel oven, see Fig. 61, in the case of mixed trades. This arrangement lends itself well to a site where there is a very narrow frontage and plenty of depth. The sketch has been prepared on this assumption, and shows a bakery standing on a piece of ground 15 ft. 4 in. in width. This might be still further diminished by lessening the width of the passage round the stokehole, which in the plan is 3 ft. wide. By resorting to the plan of having the oven fired at front and within the bakehouse, Fig. 4, Plate VIII, the total width might still further be reduced to 10 ft. inside and 12 ft. 4 in. external width. Or even in this case the oven might be fired at the back by arranging a spiral staircase or step-ladder down into the stokehole from over the oven

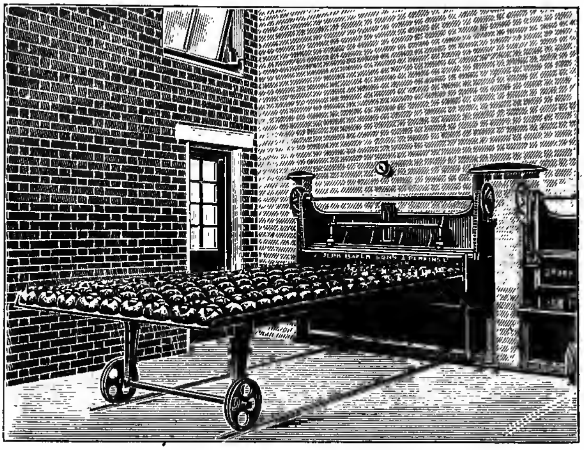


Fig. 36.—Oven for Small Bakery.

through the flour store above. Such very narrow sites are not, however, likely to often occur, and the staircase arrangement is not recommended. As drawn, it is assumed that no light is available from the sides, and accordingly small windows are placed over the ovens into the bakehouse. This plan shows the position of flour-blending, sifting, doughing, and dividing machinery, arranged in the bakehouse, and also parts of the same overhead. The engine-room is in front of the bakery, and beyond that is the bread-room. A bakery such as this forms an interesting and fairly complete installation. With this plant, especially where the draw-plate has over it a peel oven, or is of the two-deck variety, an extensive and varied trade may be done, and instances are known in which over a hundred sacks (280 lbs.) per week have been regularly turned out with similar equipment, provided sufficient space for dough trucks be available. The machine plant indicated could very well turn out sufficient work to warrant the erection of another oven beside that shown, making of course the bakehouse correspondingly wider. With increased width rearrangement of space would permit the depth to be reduced. Fig. 36 shows an oven such as this bakery might have and Fig. 37 a view of a bakery fitted with two-deck draw-plate ovens and machinery on a small scale.

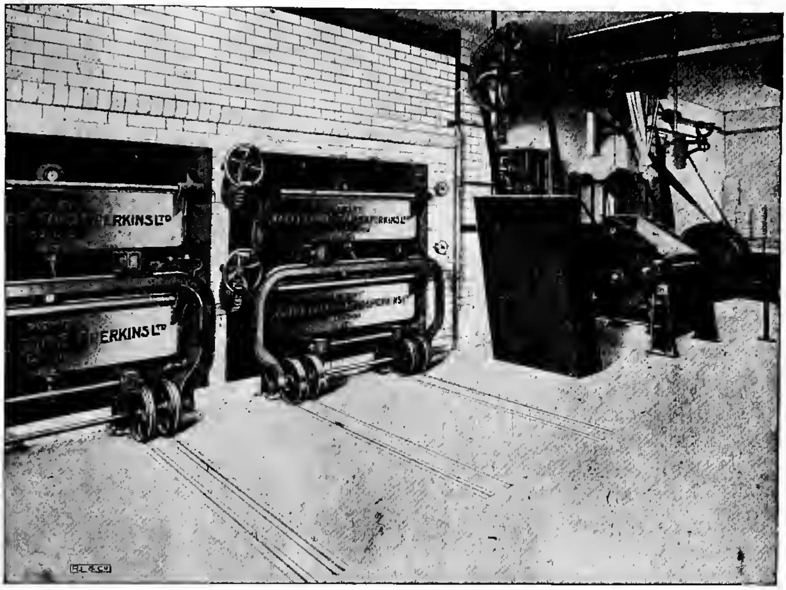


FIG. 37.—Interior of Small Machine Bakery.

556. Shop and Overhead Bakery.—The designs given on Plate IX take into consideration a business which is supposed to be in the main street of a good neighbourhood where the exigencies of the circumstances demand both bakehouse and shop to be in close proximity. It is assumed that the only access to the premises is from the front or street side, there only being at the back a limited amount of air and lighting space, which cannot be utilised in any way in connection with the manufacturing operations of the business.

Regarding the shop itself, much must of necessity be left to the nature of the business and the individual taste of the proprietor. It goes without saying that window space is required for the display of goods; this is provided by two windows, each about 10 ft. in length. On the one side of the shop is a counter, and the other is fitted with a table, which may also be used for counter purposes. Toward the back of the shop some small tables are placed, for the purpose of serving light refreshment —tea and coffee. Descending from the back of the shop is a staircase leading to lavatories and retiring rooms in the basement. These are indicated by dotted lines on the ground-floor plan. A passage from the bottom of the staircase leads to one set of lavatories and w.c.'s on the left hand. Another similar set is reached through the room shown under part of the bread-room. This basement room, with the adjoining conveniences, could be retained for the staff, the others being reserved for the accommodation of customers, and both kept separate and distinct from each other. This basement might also be used for the preparation of light refreshment to be sent up by a small lift fixed by the top of the stairs.

It being assumed that the only approach to the building is from the front, means of ingress and egress to the bakery have been provided by a side passage on the right hand of the shop; this goes right through to the back of the building, and has doors leading into the bread-delivery room and the office.

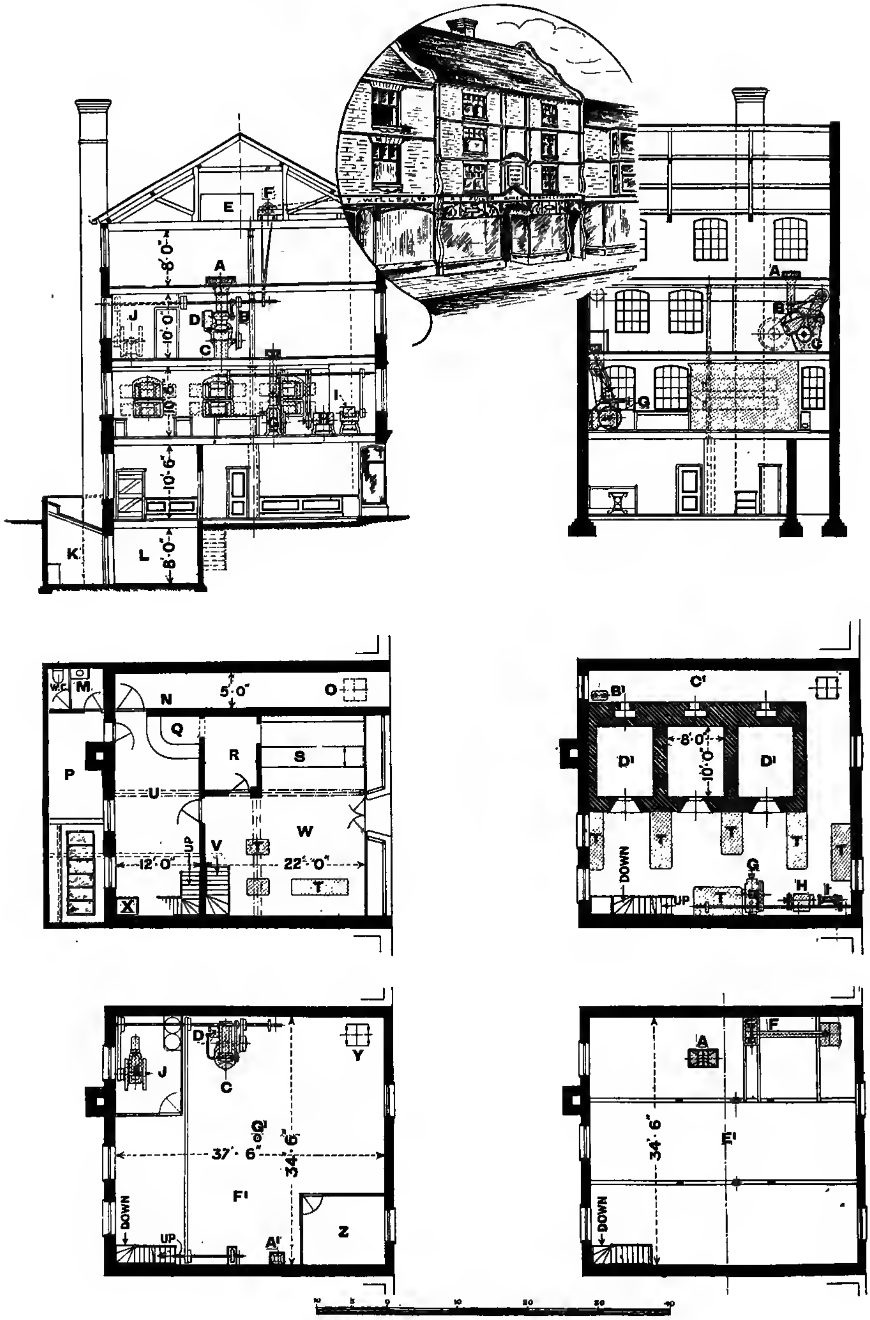
As it is no longer possible to have a new underground bakehouse, the bakery is shown overhead, similarly to the not unusual plan of having hotel kitchens, etc., at the top of the building. Let us now rapidly run through the general arrangements of the bakery. As already explained, the shop is on the ground floor, with lavatories in back part of basement, opening out in area behind. At the rear of the shop is the bread cooling and delivery room. On the first floor is the bakery, containing the ovens, loaf dough divider, and moulding tables. Other machinery and the engine are arranged on the second floor, while the flour stores are on the third floor. A more detailed examination of the arrangements may be made by following the flour from its entry into the place to its departure as bread. Being situated on a main and busy thoroughfare, all flour will have to be delivered either early in the morning or preferably late in the evening when the shop business is over. The flour van would be backed against the side entrance and the flour drawn up at once to the third floor by the sack hoist some three or four feet in from the door. The hoist itself is fixed overhead in the flour-room, and draws the sack up through the trap doors on each landing; in this way flour or other material may readily be brought from a van at the side entrance to any desired floor. Where considered necessary flour-blending machinery will be fixed underneath the third floor, and arranged so as to be worked from the flour store (paragraphs 574 to 575). The hopper, through which the flour passes to the sifter, is also on this floor, the sifter itself being bolted up underneath the joists, as shown on the sectional drawings. From the sifter the flour passes into the doughing machine. The sifted flour, together with water from the tempering tank and yeast or ferment, as the case may be, is converted by means of the kneading machine into dough. For ferments and sponges a room has been provided in one corner of the machinery room, where they may be kept at an equable temperature and free from draughts. The size of this room may of course be varied to suit particular requirements. A cake machine and whisk are shown on the first floor, but these and other machines required could easily be arranged to suit amended requirements. The doughs are allowed, after being made, to stay on the second floor until ready, and are then cut out of the troughs and discharged through a hopper on to the moulding table or into the dividing machine on the floor beneath. The machinery as shown is driven by a gas engine fixed in the one corner, from which runs a line of shafting along the wall.

On the first floor are the divider, cake machine, whisk, the moulding tables, and the ovens. Although the authors are advocates of drawplate ovens, they have here shown a series of peel ovens, as these are still largely used with mixed trades such as this bakery would be suitable for, but draw-plate ovens could be arranged if preferred. The ovens shown are two-deck, fired from the back, and should preferably have separately fired baking chambers giving absolute control of temperatures (see paragraph 602). The fuel for these ovens is coke, and this, on being brought as usual to the bakery in sacks, is hoisted direct to the third floor and taken into the coke store. The ashes are put into a portable closed sanitary bin for removal once every twenty-four hours. This bin is sent down bodily by the sack hoist, and handed over to the dustman on the occasion of his daily visit. At the far end of the stokehole is fixed a small vertical boiler for the production of hot water for general purposes. The flue from the ovens is carried into a chimney stack built against the back wall, where it cannot become a nuisance to neighbouring property. The ovens themselves are supported on girders carried between the back wall and the wall dividing the shop from bread room, and resting with their front ends upon a girder carried by the pillars and side wall. The baked bread is packed in portable racks, and taken below by means of a lift into the cooling and delivery room.

From the cooling-room one would naturally like to be able to load barrows and carts at the back, but this, according to the conditions, is impossible. Arrangements have therefore been made for delivering through the side door. A delivery clerk checks the bread as it goes out. The bread racks should not exceed 2 ft. in width, so that they may pass each other in the 5 ft. passage. This passage might be used at night for the purpose of keeping barrows, as some six or eight could readily be stowed away in it. A door leads direct from the cooling-room into the shop. Through this all shop goods would be brought, and, if found absolutely necessary, bread barrows could also be filled this way in the early hours of the morning, in addition to the use of the side entrance. On this floor is placed the office, which, as situated, controls the shop, the side passage, cooling-room, and delivery clerk's desk. From the cooling-room, through a door leading into the backyard, are reached the workmen's lavatory and w.c. With sufficient space at the rear this accommodation might well be enlarged.

Such, in brief, is the outline of the bakery and shop fitted for a large and high-class family business in a first-rate locality, but on a severely restricted site. The exigencies and nature of the business, together with the actual size and proportions of the premises, must all affect the precise nature of arrangements in each individual case. Such plans as are here given can only touch on the general principles involved in the arrangements, which in themselves lend themselves readily to considerable modification. The following references explain the drawings shown on Plate

PLATE IX. Plan of Shop and Overhead Bakery.



IX: A. Blending Hoppers; B. Flour Sifter; C. Kneading Machine; D. Tempering Tank; E. Water Tank; F. Hoist; G. Dough Divider; H. Cake Machine; I. Whisk; J. Engine-room and Gas Engine; K. Lavatory and Cloak Room; L. Basement; M. Men's Lavatory; N. Wall supporting Ovens; O. Side Entrance; P. Open Yard; Q. Delivery Checking Clerk; R. Office; S. Counter; T. Tables; U. Cooling and Delivery Room; V. Down to Lavatory; W. Shop; X. Lift; Y. Hoist Trap Door; Z. Ferments and Sponges; A.[1] Shoot; B.[1] Water-heater; C.[1] Stoke-hole; D.[1] Two-deck Peel Ovens; E.[1] Flour Store; F.[1] Dough Room; G.[1] Column.

557. Bread and Cake Factory and Automatic Machine Bakeries in General.—No attempt will be made to describe the buildings and equipment suitable for a very large business, particularly as the equipment is not very different to that which forms the subject of this paragraph. The plant in very large bakeries requires to consist merely of more units rather than units of larger size and capacity. It may be said at once that modern development in Great Britain tends to replace small bakeries by others of medium size rather than with very large ones—the latter not being necessarily at a very great advantage over the former owing to the difficulty and expense of delivering bread over a very large area. In large cities it would be better policy to erect several bakeries of medium size in preference to one large bakery, and with centralised office management, and a good organisation to supervise the various bakeries, there is the less reason to fear ill effects from decentralisation in regard to manufacture; because with the automatic machinery available today it is impossible for the output to fall short of the standard, or for the cost to exceed the same, owing to the automatic machines acting as pacemakers. It is necessary of course to have efficient foremanship in each bakery, but as this is requisite in any case, there is no disadvantage in this respect. For the purpose of our present observations it is necessary to adopt some classification, in regard to the size of bakeries, in order to convey some idea of the extent to which the specialisation of machinery and equipment should be carried.

558. When Machinery Pays.—It is one of the most important questions when designing a modern bakery to determine exactly how far the provision of machinery should go. At the time of building, when a given trade has to be provided for, some machines may not be worth installing which it is essential to have in a few years' time when trade has grown to proportions making their employment highly remunerative. If, however, no clear idea of this possibility exists at the time the building is erected, it may be impossible to provide the necessary space, or to make suitable arrangements, owing to the later wants not being provided for.

The standard of trade for a medium-sized bakery may today be set at approximately 500 to 900 sacks (280 lbs.) per week, because this is the maximum output of one automatic bread-making plant (see paragraph 594). The size of this unit is determined by technical considerations, but it may be accepted for our purposes that 1,200, 2,400, or 3,600 2-lb. loaves per hour is the maximum output of the various sizes of automatic plant which have been found practicable. If a bakery requires to deal with greater outputs than these, more than one plant must be installed. The limit as regards maximum output per week having been definitely ascertained by multiplying the hourly maximum by the weekly working hours (examples: 2,400 2-lb. loaves per hour = 12 sacks per hour × 60 hours working per week = 720 sacks; or 2,400 1½-lb. loaves = 8 sacks per hour × 50 hours working per week = 400 sacks per week, etc.), it may be asked, what is the lowest output per week, on which such a plant would pay? The answer to this question is not a simple one—many considerations go to determine the correct course in each individual case, but it can be affirmed that it would never be advisable to attempt an answer without the assistance of the bakery engineer who specialises in automatic machinery. Two bakeries with precisely similar, and on the face of matters perfectly sufficient outputs, may be very differently placed as regards the composition of their respective trades. It may pay brilliantly to have a full installation in the one case and yet not in the other. Such matters can therefore only be determined after full investigation of the whole of the circumstances. It will be appreciated that the authors can only lay down the general rules which should be followed, and that such approximate facts, as are here quoted, apply to average cases.

The minimum trade for a full automatic plant may be taken at 250 sacks (280 lbs.) per week of reasonably uniform loaves. On this output no one need hesitate as to the remunerativeness of the installation, but it may be here remarked that owing to the uniformly better bread which would result under tolerably good management in the bakehouse, an increase in the sales may be looked for; this increase will be all the greater if the sales are smartly pushed, although that is not what is here meant —the increase referred to is automatic and due to a better article. To the uninitiated this may sound "too good to be true," but the statement is nevertheless based upon a well authenticated fact. Any one installing a plant on a trade of 250 or 300 sacks will therefore, in all probability. soon have a larger trade with which to keep it employed, and all increases will inevitably bring down the cost of production per sack, because no increase in the number of men working the plant is required for working it to its fullest capacity.

For bakeries with trades under 250 sacks per week smaller plants are made, both as regards the actual machines as well as in certain combinations, by reason of fewer machines being employed in conjunction with intermittent working. Thus, a so-called semi-automatic plant will pay in the case of a fairly uniform trade of 100 sacks per week and upwards, and the cost per sack in labour will be only fractionally less good than that obtained from full-sized installations.

Under one hundred sacks per week the employment of a divider and a "Flexible" moulder (that is a moulder equally adapted for turning out tin, cottage or coburg bread as well as smalls) will pay down to weekly outputs of 60 or 70 sacks. This is contrary to the opinion still very generally held, but as actual cases exist which prove the statement, the authors do not hesitate to give it all the weight they can command.

Under 100 (one hundred) sacks per week no up-to-date bakery should be without at least a divider, provided the machine is designed on the proper principles, and does not fell or otherwise injure the dough. It is no use employing a machine merely for the sake of having a machine, and many a user loses in reduced quality all and more than he can save in labour. Good modern dividers are very accurate, much more so than any commercially obtainable hand-scaling, they act as pacemakers, and are absolutely reliable machines if looked after with reasonable care and kept clean.

Bakers with trades no greater than 25 sacks per week in bread should by no means assume that a divider will not pay; even on such comparatively small outputs as 25 sacks (280 lbs.) per week these machines pay well in many instances. It may be taken that a suitable divider will pay in any business doing a reasonably uniform bread-trade and employing three men.

559. Large Bakeries.—Returning now to the subject of large bakeries, and having determined upon the nature of auto-machinery to be installed, the question of ovens should next engage attention. The subject of ovens is fully dealt with elsewhere (paragraphs 597 *et seq.*), and for factory working, *i.e.* wholesale production, no type can today be really seriously considered in Great Britain other than the draw-plate oven, the continuous travelling oven—or perhaps in Scotland and some parts of Ireland, the "Coverplate Oven." The size of baking plate for Drawplate and Coverplate ovens must be determined to suit the style of loaf. Cottages, coburgs or tins, are most conveniently dealt with in one sack batches and on plates with a maximum width of 6 ft. "Oven-bottom" or close-set bread, if not in association with any of the first-named varieties, can be handled perfectly with plates up to 8 ft. 6 in. in width, as can also "Scotch Bread." Batches may be taken to vary from one sack cottage to 2½ sack "Scotch" batches, but to illustrate the procedure, we will adopt the former as a standard. Assuming a full size auto-plant to be decided upon, this will have an output in 2-lb. loaves of 12 sacks per hour. The batch ovens will bake continuously one batch per hour—hence 12 one-sack drawplate ovens will be required in such a bakery. Where travelling ovens are in question considerations of too technical a nature arise to enable the advice of bakery engineers to be dispensed with.

The preceding remarks (in paragraph 558) refer mainly to machines dealing with the dough after it has left the kneading machine. Naturally, hoists, sack-cleaners, blenders, storage hoppers, sifters, tempering tanks, and kneaders have all to be considered; but as these have been longer on the market and are better understood generally than the automatic plants, and are also fully referred to in their respective chapters, no special reference is here made to them.

The authors have advisedly enlarged upon the auto plants because they are today the key to successful designs for large bakeries, and because no architect can be properly instructed as to the nature of buildings required, before the bakery proprietor is quite clear as to his requirements in regard to machinery. The architect who has had anything to do with modern machine bakeries, will agree that his clients do best first to consult the bakery engineer, who will prepare such plans and particulars as will alone make it possible for him to give his client a perfectly designed bakery.

This may be a new order of things, but it is undoubtedly necessary to prominently advise the above course if mistakes are to be avoided, and the authors consider no other apology necessary.

CHAPTER XIX.

THE MACHINE BAKERY AND ITS MANAGEMENT.

560. Sanitary Considerations.—The operations of kneading and working dough involve severe manual labour in a heated atmosphere; it is impossible to conduct these processes without more or less contamination of the bread with emanations from the skin of the workers. In the best conducted bakeries this evil is reduced to a minimum by insistence on scrupulous cleanliness on the part of the workmen; still, even the utmost care cannot entirely abolish the evil. For the strongest of sanitary reasons, both on behalf of the public and of the workmen, operations on dough demand mechanical appliances rather than manual labour. So forcible are these reasons, that the expense of kneading machinery and its convenience, compared with ordinary manual processes, become merely secondary considerations.

561. Bakehouse Machinery.—In describing the machines required in a bakery, some classification will be necessary; it is therefore proposed to commence with an account of the various sources of motive power, such as steam, gas, and other engines. Following on this in natural sequence, the means of distributing power, embodied under the general term of "gearing," engage attention. It is then proposed to take the flour as it enters the bakery and follow its history through each mechanical appliance employed, discussing and describing each in detail. In this latter connection, hoists, blending, sifting, kneading, and other machinery, as well as ovens, will be included.

562. Motive Power.—One of the great objects of machinery is to spare workmen from severe manual labour. There are comparatively few machines which are profitably worked by hand, and a man must rightly be regarded as by far the most expensive source of power. For flour-sifting purposes machines may be obtained which work well by hand power, the reason being that comparatively little force is requisite to drive these machines. Various kneading machines are also supplied which may be driven by hand; but it is more than doubtful whether any hand machine can make a mass of dough with the total expenditure of less force, measured in foot-lbs., than can the baker working direct on the dough. The worker's task may be lightened by slowing down speed by means of gearing, but in such cases the compensation is made by the greater demands on time. In civilised countries hand-worked machines for the bakery cannot be recommended, as experience proves that operatives strongly object to work the handle of a kneader.

In cases where steam power is available, that of course forms a useful and convenient mode of driving machines. Thus, if the bakery adjoins some other building, such as a flour mill, it is economical and convenient (from the baker's point of view) to take his power from a steam engine there running, *provided it is always available when he wants it.* Or if he can similarly gain access to a boiler and draw off high-pressure steam whenever required, it will be well to fix a small steam engine and run it as a source of power. These conditions are, however, rare in Great Britain; and certainly the laying down of a steam plant, consisting of boiler and engine, is bad economy for the ordinary baker's requirements. For these reasons steam engines are comparatively little employed in bakries except in countries where the severity of the climate demands steam for heating purposes in any case.

What, then, is wanted is a source of power that can be started at a minute or two's notice by a man not necessarily trained as an engine driver, and which can be as quickly stopped, the expense of the source of power being arrested simultaneously. Further, the motor should not be, even in case of neglect, of a nature such as would lead it to be a source of danger to the employés or the building. These requirements are met most fully by both gas and oil engines, and especially by electric motors.

563. Electric Motors.—Undoubtedly the electric motor is the most compact as well as the most convenient prime mover. Wherever electric current is available at a reasonable cost it should be preferred to all other means of obtaining motive power. A judicious arrangement of motors will often prove at least as cheap in running cost as that of any other method. The need for good judgment arises out of the fact that although a motor, while running at its maximum output, may cost more than some other source of energy, yet it can be so readily started and stopped that it proves in the end cheaper than an explosion engine, which is necessarily left to run throughout the working hours in a bakery. The electric motor should in fact be in motion only while required to perform actually remunerative work. To merely replace an engine by a motor to drive a line shaft would in many cases indirectly involve the waste of much current, as the motor would be left running when there would be no need whatever for it to be in motion. The best plan is to couple such machines as are required to run simultaneously—say kneader and sifter, or divider and moulding plant—and let each group be driven by its own separate motor. As this plan obviates all long lengths of shafting, it frequently does not prove more costly to instal than one motor with a great deal of shafting, etc.

Again, the hoisting in of flour frequently takes place at a time when no other machinery is required to be in motion; the same holds good as regards the fewer and much smaller machines required in the confectionery department, as compared to the bread bakery.

It will be seen that if the stopping of the machines is dependent upon the stopping of the motor no waste of current can occur without malice—a contingency which need not be taken into account in this connection. Illustrations of machines with direct coupled electric motor drives are given later in this chapter.

Some hesitancy in adopting electric motors existed in the earlier days of public electric supplies, and not without reason, owing to the apparent delicacy of much which forms part of electrical machinery; but no reason exists today why any one should hesitate to adopt electrical working from any fear of breakdowns. Electric motors and all pertaining thereto are today at least as reliable as any other machinery, and types of motors are now available (notably the totally enclosed machines) which are eminently suitable for bakery conditions. As with internal combustion engines, it is advisable to have each motor of ample power for its work. but that is no more necessary in these cases than with any kind of machinery. It is also not so very long ago that certain alternating currents were the cause of difficulties in motors, but any lingering suspicions in regard to these troubles may be now confidently dismissed. The authors know of no current commercially available in Great Britain that cannot be safely relied on for bakery purposes, Any attempt to explain the principles of the various electric motors which may have to come under consideration would be of far too technical a nature to come within the scope of this work; the authors have therefore confined themselves to the purely practical aspects of their application to bakeries, and must leave all matters of detail to the local electricity department or the consulting electrical engineer.

564. Gearing and Power Transmission.—The problem of transmitting power in a bakery is practically confined to the conveyance of rotary motion from one shaft to another. This transmission of power may require to take place from a prime mover to a machine, or group of machines, or it may involve distribution over a building covering considerable distances. In the latter case electrical distribution, as described in the last paragraph, provides the best solution of the problem, whether current be available from a public supply, or has to be generated on the premises. No known means can compare for efficiency and convenience with electrical driving, if the points at which power is required are numerous and at all widely separated by distance. The determination of the best arrangements for electrical distribution cannot, however, be laid down conveniently within the space available in this work. The power scheme must, moreover, be entirely adapted to the requirements of each case, and this is too complicated a matter to be adequately undertaken as a piece of general advice. The average bakery, however, does not call for anything very elaborate, and the authors propose to confine their remarks to the forms of gearing usually required.

565. Shafting.—For driving a group of machines from one common source of power, a sufficient length of shaft is employed to enable pulleys to be fixed thereon, opposite to the driving pulleys of the machines which are to be set in motion. This shaft is commonly called a line shaft. If subsidiary shafts are required, either to enable a further group of machines to be supplied with power or for other reasons, such shafts are called countershafts. The shafting itself is now usually of mild steel, it should be true in diameter and perfectly straight, and in lengths suited to the actual requirements. In determining the lengths, it should be borne in mind that 20 ft. forms the maximum which is practicable; that the couplings used for joining up the various lengths forming a line shaft should as far as possible be close to bearings, and that as few pieces of shaft as possible should be employed to make one line shaft.

A shaft will, for a given size, transmit power proportionately to its speed of revolution, hence the higher the speed the smaller the diameter required to transmit a given power. There are, however, various reasons why the speed should be kept within limits, among these it is sufficient to mention the two most important. The first is that bakery machines require on the whole low speeds, and have therefore to be designed with considerable gearing in themselves, so that their driving pulleys shall be capable of running at a reasonably high speed. Too high a line shaft speed would therefore call for badly proportioned belt drives. The second reason is that great care is necessary in arranging high speed line shafts, especially because very careful balancing of all pulleys fixed thereon is necessary to prevent excessive vibration. It may be taken that that most suitable speed for line shafts in bakeries is from 140 to 160 revolutions per minute. The diameter of a line shaft must therefore be proportioned in such a manner that, at this speed it is capable of safely transmitting the power, it is intended to convey, to all the machines that will be driven from it.

566. Surface Friction Bearings.—A good type of bearing is one which has a white metal running surface, is fitted with an oil well, and has ring lubrication. Many makes exist which possess these features, and the task of selecting the cheapest and most efficient should be considered to belong to the province of the bakery engineer. "Ring lubrication" is a fairly modern innovation in spite of its effectiveness and simplicity, and as it is the best and most automatic device for ensuring the continuous lubrication of bearings, a short description must here be given. The bearing is so constructed that under the lower running surface a reservoir or chamber is formed which is filled with oil up to a given level. At each end of the bearing surface, but within the casing, an annular space surrounds the shaft for the purpose of allowing a ring, usually formed of stout wire or flat metal strip, to hang on the shaft. The diameter of this ring is considerably greater than that of the shaft, thus permitting the lower portion of the ring to dip into the oil contained in the oil well or reservoir. As the shaft revolves the ring revolves also, and in so doing conveys the oil from the well to the shaft and over the top in a continuous supply. The oil thus conveyed is much more than is required by the bearing, which therefore is always perfectly lubricated so long as the reservoir contains oil, but as the surplus all flows back to the well, one charge lasts for a very long time, and there is absolutely no waste.

The bearing described is so good and reliable and withal so inexpensive that all older types are now entirely obsolete, and should on no account be fitted for new installations.

567. Rolling Friction Bearings.—Even better types of bearings are provided by roller- and ball-bearings. Surface friction being entirely absent in these, they absorb considerably less power, and are therefore more economical. Several good makes exist and are absolutely trustworthy, and there can be no question that where first cost is not a governing consideration, their adoption in preference to all others must be recommended, as the additional cost is undoubtedly more than saved by the economy effected in power.

568. Bearing Supports.—Bearings are carried in a variety of ways —in a wall box, fixed in a wall at the end of a line shaft, or where it passes through a wall; in a wall bracket which is bolted to a wall; in a hanger suspended from a ceiling, or in pedestals supported on a floor, pier, or girder. A detailed description of these various fittings can scarcely be necessary, but one essential should be insisted upon with all. That is, that all bearing supports should be of so-called self-adjusting type, which means that the actual bearing shall not be rigidly bolted to a fixed surface, but should be so supported by adjustable screws, that the exact alignment of the shaft may be readily obtained by the use of the screws, which are then secured by lock nuts. The alignment of a shaft should be perfect, otherwise it will absorb infinitely more power in being driven, and may be even subject to breakage, or seizing in bearings. It is not sufficient to line up a shaft properly when it is new—a very slight settlement in the building, or the heavy loading of upper floors may destroy the original alignment, and ready means for readjustment are therefore necessary.

For similar reasons, bearing supports should preferably be carried from the solid walls of a building. A floor may be of ample strength to carry the weight it has to bear in everyday use, but it can never be absolutely rigid. The floor of a flour store, for instance, may carry many hundreds of tons of flour, and do so with perfect safety, yet its deflection will vary according to the load—just in the same way that the best and strongest modern bridge is designed to deflect under its moving load. A shaft supported in hangers from such a floor will obviously follow its movements, and can therefore never be in perfect alignment, except possibly when the load corresponds exactly to that which existed when the alignment was made. These variations may not and are not likely to be serious enough to endanger the actual working of the shafting, but they must cause the absorption of more power than under ideal conditions would be the case. It follows that hangers and pedestals carried on upper floors should be avoided as far as possible, although they may be used quite properly for short lengths of shafting.

Bearing supports should be placed only after careful consideration; *in all cases,* either so that they can be quite close to the pulleys, or so that the machines can be fixed to bring the pulleys close to the supports. This is very important in bakeries, because owing to the peculiar nature of bakery machines, high belt speeds cannot be conveniently arranged for, and the belts have consequently to be kept fairly tight, especially as space is also of great importance and shaft centres are as a rule not as widely apart as would otherwise be desirable. For the same reasons, the bearings should not be too far apart—it is advisable to limit the distance of bearings from one another to 6 ft. in 2 and 2¼-in. shafts, 7 ft. in 2½ in., and 8 ft. in 3 in. shafts. Smaller shafts than 2 in. should not be employed. Attention is again drawn (see paragraph 546) to the desirability of avoiding piers on the inside walls of buildings—so that there should be no hindrance to the fixing of bearing supports on the plain wall surfaces in such a manner as to enable unrestricted compliance with the above considerations.

Each complete length of shaft should be fitted with collars at each end of one bearing only, in order to suitably limit side play. The collars should have no projections, so that the danger of attendants' clothes being caught up may be avoided. The same remarks apply to couplings for joining up the several lengths forming one line shaft.

569. Pulleys.—All pulleys, except the fast and loose pair, from which the line shaft derives motion, should be split—that is to say made in halves, so that changes and additions can be made without having to take down or disturb the shafting. The fast pulley should be keyed on and the loose pulley should be self-oiling and slightly smaller in diameter than the fast, to reduce the belt-pull when running idle. Except the fast pulley, no pulley should be keyed on to the shaft; the use of self-gripping (preferably "screw boss") pulleys ensures the shaft remaining undamaged and avoids the necessity for cutting keyways. In fixing "screw boss" pulleys, care should be taken to place these on the shaft in the correct way, which is of course that which ensures that the belt-pull will keep the screw boss tightened. For reversing shafts, screw boss pulleys are useless—other self-gripping pulleys must be used in such cases. For the speeds above recommended (140 to 160 revolutions per minute) cast-iron pulleys may be used throughout. All pulleys should be crowned, except loose pulleys, and arranged to be of as large a diameter as circumstances will permit. The speeds of shafts are in inverse proportion to the diameter of the pulleys on each, hence the diameter of pulleys required to drive one shaft from another at a predetermined speed is readily ascertained by an ordinary proportion or "rule of three." Example: an engine shaft runs at 200 revolutions per minute and the line shaft is required to revolve at 140. If an existing pulley of 24 in. on the engine has to be taken into consideration, then as $140:200::24:40 =$ diameter of pulley on line-shaft. If choice can be made without reference to an existing pulley, first decide upon the maximum diameter that is possible (or desirable) for that pulley which is limited by its surroundings, and proportion the others as before.

The reason why pulleys require to be as large as possible is that the power, which a given belt can transmit, is proportionate to the speed at which it travels, and therefore the higher the belt speed the greater is the power the belt can transmit; or inversely, to transmit a given power, the higher the speed of the belt the smaller is the belt required. It is necessary to bear in mind that owing to the greater circumference of the larger pulley, the belt speed is higher with larger diameters than with small, in direct proportion to the increase in diameter, the pulley or shaft speed remaining constant. It follows that, assuming a machine to have been fitted with a pulley inadequate to absorb the necessary power for driving it (which will show itself by persistent tendency of the belt to slip or run off in spite of machine and line shaft being perfectly lineable), the correct remedy is to increase the size of the pulleys on the machine and on the line shaft in the same proportions. This alteration will leave the speed of the machine unchanged, but will at once remedy the defect, if the increase in belt speed is sufficient. To double the belt speed will double its capacity for conveying power and so on in proportion.

570. **Belting.**—For all ordinary purposes leather belting is recommended for bakeries. A good dressing (such as "Clingsurface") periodically applied should be used sparingly and will act as a dressing and keep the belting in good condition. Resin and other forcible means of increasing adhesion should be avoided. The best makes of bakery machines are designed for ample widths of belts, which therefore give no trouble from slipping, and if reasonably long centres (distance from shaft to shaft) are allowed, need not be kept unduly tight. For joining up the ends of belts "Harris" fasteners are very convenient and hold excellently, if properly put on. The ends of the belt should be marked off exactly true with a carpenter's square, and cut perfectly clean and at right angles. Next see that the belt is properly round the pulleys and shafts which are to be connected. Then turn the belt so that the inside lies uppermost, and place the joint down on the fasteners with the teeth upwards without any twists, and place the ends of the belt in exactly their right places on the same. Get some assistance to hold the belt in exactly the right position, and drive the leather down on to the teeth of the fasteners. With the joint properly made there is no danger of the fastener tearing out.

Do not use the hammer direct, but employ two blocks of wood used endways to the grain—the one block should form the bed, the other should be firmly pressed on to the belt close to the joint. Thus the leather will be driven into the teeth by the agency of the wood, under the blow from the hammer, without damage to the teeth. Be careful not to eliminate the curve given to the fasteners by the makers. Drive the fasteners home with as few heavy strokes of the hammer as possible in preference to many light taps, which only cause the fangs of the fasteners to be loosened in the leather. Another excellent means of joining belts is to use a specially prepared flexible wire—this is sold with suitable tools for punching the necessary holes in the belt, under the name of "Malin" outfit. "Harris" fasteners are useless where the belt is bent in both directions, as, for instance, when taken over guide or "jockey" pulleys; in such cases ordinary lacing or wire lacing must be employed.

The most common application of a belt for the transmission of power is found in the case of two parallel shafts running in the same direction. In mounting a belt observe the arrangement of the joints, *i.e.,* the places where the separate lengths of leather from which the belt is made are connected together. The belt should be put on so that the trailing end of each piece last reaches the pulley—a moment's reflection while examining the belt will make the reason for this plain. When joining up a belt with leather lacing, the ends should be pared down in order to make a "scarfed" joint of uniform thickness. This should be arranged so that the joint follows the same direction as others in the same belt. If double belts are used it might be difficult to obtain a satisfactory "scarfed" joint, and the ends should be butted and a separate piece of belt laced on, jointly to both ends on the outside of the belt, *i.e.,* not touching the pulleys; thus an even inner surface will result. In joining up the ends of a new belt considerable allowance must be made for stretching: it is not possible to give exact instructions as to the amount of such allowance, but a very little experience will provide the necessary judgment. In any case a new belt will stretch further than can be allowed for in first joining up, and will need "taking up" after it has been at work for a little while; with newly installed machinery it is therefore as well to go carefully round all belts before starting up the day's work—this precaution requires but a few moments and will save the inconvenience and loss of a stoppage during working hours.

It should be, but actually is not, superfluous to here advise that sufficient belting should be kept in stock (not kept in a hot place), together with fasteners, laces (wire) and tools, to enable repairs to be quickly executed when necessary.

If it is desired to drive two parallel shafts in opposite directions, the belt is put on "crossed," *i.e.,* it must run from the under side of one pulley to the upper of the other. Shafts at right angles to one another can be driven by belting quite satisfactorily, if the one is above the other at a sufficient distance to give a reasonable length of "drive." The pulleys are arranged in such a manner that the belt leaving the "driven" pulley has a central lead to the "driver," and equally on leaving the "driver" pulley leads centrally on to the "driven" again. The shafts and pulleys must be accurately fitted and can only work in just the one way which ensures correct leads; but the condemnation of such drives which one occasionally meets with is not justified, and arises out of unsatisfactory experiences due to badly arranged gearing. Properly proportioned and erected, the so-called "quarter twist drive" may be as satisfactory as any other belt drive.

To enable a machine to be driven which has to stand well away from the wall, or to get into an adjoining room, or for other reasons, a belt drive may be required to run over guide or "jockey" pulleys. The plan is not a good one and is unsuitable for considerable powers, but if well arranged may prove quite satisfactory for light work. It should only be employed where other means are not available, and should then be so arranged that the belt is not required to be very tight in order to transmit the necessary power.

Before turning from the subject of shafting, bearings and pulleys, it may be useful to call attention to a point very commonly overlooked. The power absorbed by the shafting itself, that is to say, before the brake horse power or power actually given off by the prime mover can become available at the machines, is very considerable. One short length of shafting of course does not require a startling amount, but it may be considered a safe rule not to allow less than 2 to 3 h.p. in fixing upon the size of the prime mover, when making provision for the requirements of the average bakery (with, say, 20 to 30 ft. of shafting). In larger establishments, however, involving shafting in three or four and even more different places, the power absorbed "on the way" to the machines is much more considerable and requires to be carefully gone into. There are many bakeries where the power required for driving the hoist on the top floor (for getting the flour in during the day, when it is the only machine for which the engine is being run) is three and four times as large as the power required by the hoist itself. A similar condition of affairs can often be found in bakeries when a small whisk or cake machine in the confectionery department causes an engine and a great deal of shafting to be kept running for the best part of the day. Seeing that a better scheme might in many cases avoid this considerable and continual waste of power, it will be clear that even for matters of quite simple and everyday practice it may be wiser to be guided by the advice of competent bakery engineers, rather than ostensibly to save a few pounds by merely buying individual machines and having the rest of the installation put together in an amateur fashion.

Cases have been met with where owners have quite erroneously blamed machines for absorbing a great deal more power than was possible, from no other cause than that stated above. It is the fashion to inquire into horse powers and weigh all kinds of *pros* and *cons* with much care, but this is worse than useless if a supposed saving of a little power in a machine is to be nullified by badly designed accessories or transmission arrangements. The fact is, that as regards power absorbed by machines, the user may well leave that subject to the engineers; it will pay him better to confine his inquiries, when selecting machines, to the question of their efficiency for his daily work. The machines that will pay him best are those which produce the finest article—no matter what their price may be or the horse power they absorb—especially as it is rather in the nature of things, that the machine which punishes the dough least is also likely to use the least horse power if proper regard is had to the work done.

571. Lubrication and Maintenance.—The modern device for ensuring lubrication has already been fully dealt with as regards bearings and loose pulleys for shafting. The older methods are not referred to, as modern developments and advice for future conduct alone form the subject of this chapter on machinery. It may be as well, however, to say that oil is considered the only suitable lubricant for shafting, at least in the opinion of the authors, as solid grease lubricant, excellent as it is for bakery machines proper, involves more constant attention than can be relied upon where bearings, etc., are out of reach and in inaccessible places. That no prejudice exists against solid lubricants, will appear quite clear after a perusal of the description of bakery machines. In connection with lubrication, special attention requires to be drawn to the necessity for using bearings from which leakage or overflow is impossible; as this is obvious, nothing further need be said.

As to maintenance, it cannot be sufficiently insisted upon that the only proper course is to appoint two men specially, whose duty it shall be to carry out certain specified duties periodically. The bakery proprietor should keep a book in which he enters these duties in full—set out in unequivocal language—he should add further items, as experience shows up weak spots, so that these may be safeguarded in future, and he should satisfy himself that the person appointed has attended to his duties at the specified times in a proper manner. The object in appointing two men is to provide against emergencies. There should then always be at least one competent person available to do the work, if each of the two is made to take the duties referred to for alternate months.

The task of preparing the book of instructions is not so formidable as might appear at first sight. The manufacturers of ovens, machines and motors provide (or should provide) proper instructions; and if these are taken as a basis, and common sense, assisted by the engineers, be used, complete rules will not be difficult of compilation. That the maintenance of the proprietor's plant should be properly organised by the proprietor must be evident, because that course is absolutely indispensable in his own interests. It is no use to blame the men when something has gone wrong; it would be much better for the proprietor to blame himself for not having made adequate provision against contingencies. If this sensible course is followed, the proprietor will soon find a remedy, which will never be the case if the matter is simply left in the hands of the men.

As regards upkeep of shafting and gearing generally, the authors fear that the majority of users rarely trouble themselves until defects force themselves upon their notice. They have already said that spares for repairs of belts should always be kept handy. It is now suggested that shafting is as much an essential of an installation as the engine or the machines, and that it and all its appurtenances, as well as engine and machines, should be kept absolutely clean. If cleaning is properly done from day to day it is done in an astonishingly short time. If it is neglected until gear has to be "dug out" it is nearly a hopeless task. No proprietor should be satisfied with his bakery unless shafting and all machinery be left perfectly clean inside and out at the conclusion of the day's work. This is no counsel of perfection; there are plenty of bakeries in which this is done, but there are far more in which it is otherwise. This cleanliness is not only essential for the proper upkeep of the machinery, but it is indispensable from a hygienic point of view, as well as from the business standpoint. Let each bakery owner throw his bakery open to public inspection all day and every day, and if it be kept in the condition in which it should be, this plan will not only compel the proper appearance and condition of the establishment, but will prove the best possible advertisement. In such cases where this plan has been tried, it has given excellent results and has led to increase of business.

572. Flour Hoisting.—Flour being, for reasons explained in paragraph 551, usually stored at the top of the building, adequate means for hoisting are among the primary requirements of a power-driven bakery. In many cases a covered cartway is formed in connection with the bread-room either within the four walls of the main building or as an outside addition.

In the former case square holes are cut vertically above one another through every intermediate flour, in such a position that the loaded flour lorry can be conveniently placed immediately under the openings. Each floor opening should be fitted with hinged flaps, normally completing the floor and preventing all danger from open holes. These flaps should be stoutly constructed and made to hinge upwards; a hole is cut in the centre of the joint between the two large enough to allow the cast-iron weight-ball, which serves for causing the hoisting chain or rope to descend, to pass unobstructedly. The trap-doors should be railed off, but if this is not permanently possible, movable guard rails should be placed in position each time the hoist is used, to prevent risk of injury to passers-by. If the flour sacks are to be hoisted outside the main building, the pulley over which the hoisting rope passes is supported on a projecting beam or cathead. To prevent the flour from getting wet and to avoid the admission of cold air into the flour store as far as possible the cathead should be enclosed, and a continuation of this enclosure should be carried right down to within a convenient distance of the lorry; where the lorry stands in a covered yard, this enclosure or trunking (usually called a "lucombe") merges into the roof of the yard and is joined to the same in such a manner as to be watertight. Wherever the lucombe gives access to a floor, *i.e.*, at each floor to which flour is intended to be hoisted, trapdoors as described should be fitted, thus practically avoiding all danger to operatives in "landing" the sacks and detaching them from the hoisting rope. The centre of the hoisting rope should be clear of projections by about 2 ft., and the internal dimensions of a lucombe should not be less than 4 ft. square.

The Sack Hoist itself, except in such rare cases where it may be direct coupled to an electric motor, should preferably be of a type employing a friction drive. There are various hoists upon the market which are quite satisfactory, but none are simpler, more efficient and reliable, free from necessity of repair, or easier to work than the one here illustrated, Fig. 38.

The driving pulley will be seen close to the frame to the left of the illustration, it can be driven in either direction by arranging an "open" or "crossed" belt drive. It usually runs free, and is therefore a loose pulley. The hoisting drum, grooved to take the highly flexible steel wire rope, is pressed to the right into the brake drum by a spring contained in the projection shown to the left of the framing. The drum is therefore normally and automatically "on the brake." A slight movement of

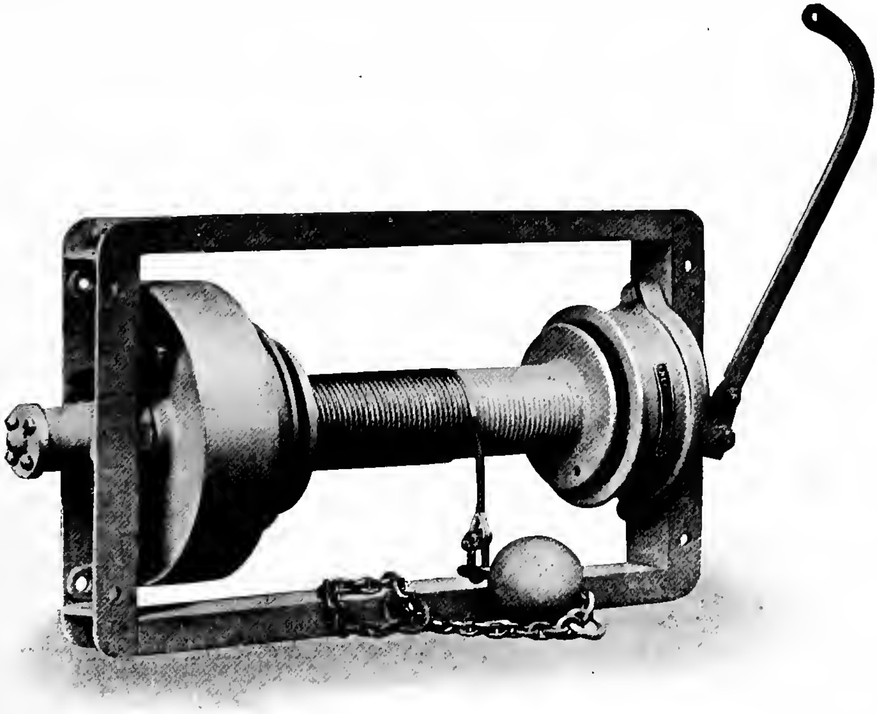


Fig. 38.—Sack Hoist.

the lever on the right disengages the drum from the brake and allows any suspended weight (the ball shown is sufficiently heavy) to descend. On letting go the lever the drum instantly returns to the brake and comes to a stop. A slightly greater movement of the lever than that referred to engages the other end of the hoisting drum with the pulley and causes the hoisting rope to be wound in, thus raising any weight attached thereto. The action is quick, safe and noiseless and allows of very delicate handling. These hoists have been in constant use for very many years and are capable of hoisting hundreds of sacks of flour per week each. They are made in various sizes, to suit the length of lift and for weights up to 5 cwts.

The fixing of the hoist is "universal"—that is to say it may be fixed to suit practically any local requirements. The best plan is to hoist direct from the drum, as each pulley over which the rope has to run means wear and tear to the latter. In practice the lever is of course worked from a hand rope carried to a convenient position.

The hoist shown is fitted with a wire rope, but it can also be supplied for use with a chain. The rope is, however, rather the safer appliance because it will not break without warning. The wear of a wire rope can be readily detected by the gradual breaking of the strands. As the broken ends stick outwards and are sharp as needles, the occasional passing of the bare hand along a wire rope will soon draw attention to wear. A rope is sound so long as the surface is smooth to the touch all along its length. Chains do not necessarily give any sign of weakness, as this does not arise merely from wear as to thickness of links; chains harden in use and may snap from this cause without notice. It is therefore necessary with all chains at least once annually to dismantle the same and send them to be annealed. Any ordinary smith or engineer's shop should be able to perform this very necessary operation, which is not difficult but requires to be conscientiously done.

The rope pulleys must be properly designed to prevent damage to the rope—it is best to obtain them from the engineers who specialise in these hoists; not only is the shape of groove important, but also the diameter of pulleys—both must be suitable to ensure a reasonable length of life to the rope. Hoists should be planned so as to reduce the number of rope pulleys employed to a minimum. The hoist is fitted with Stauffer solid grease lubrication, and the same method should be employed for the pulleys.

Hoisting Speeds must vary according to circumstances; 60 ft. per minute is quite sufficiently fast for short lifts, such as from one floor to another, but speeds up to 200 ft. per minute may be employed for long lifts.

The Hoisting Power varies of course with the speed and weight, but for the average bakery it may be taken that to provide approximately 2-3 h.p. will be sufficient.

573. Flour Storage and Flour Blending.—There can be no doubt that the aëration of flour before use in the bakehouse is beneficial as regards quality of bread produced, and that if it is carried out efficiently and in conjunction with judicious blending of different grades of flour, an advantage can be obtained in regard to quality of the blend over the market price, or inversely a profit be made if a given quality be taken as the standard.

To realise these advantages to the full is, however, by no means easy, and involves a great deal of good judgment. It may be taken that the process pays only with considerable outputs or exceptional judgment—or both.

Many so-called blending plants are not remunerative, some are even directly harmful. This principally applies where use is largely made of worm conveyors, which are most objectionable because they create dust, due to the friction inseparable from their use. It must be obvious that it is absurd to spoil good flour in this manner after the miller has gone to endless trouble and expense to eliminate dust and make his flour as granular as possible!

With modern developments of milling, blending has not the importance in an average bakery in this country which once attached to it. The important exceptions are where—

1. The large bakery, properly equipped, specialises in the matter of blending and really deals with the question on scientific lines.
2. The small bakery where the proprietor or manager possesses special knowledge and experience, and by personal good judgment, can ensure that it pays him to blend.

In all other cases, the millers can be relied upon for supplies of good blends, if judicious selection be made in buying for the requirements of the business.

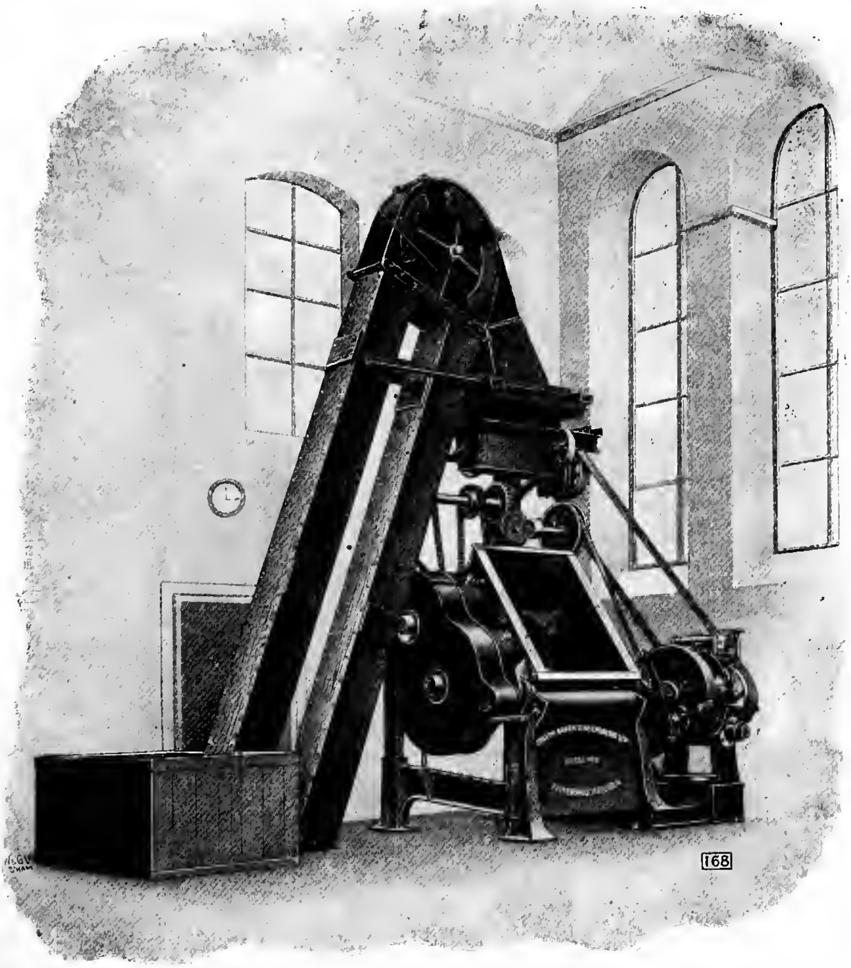
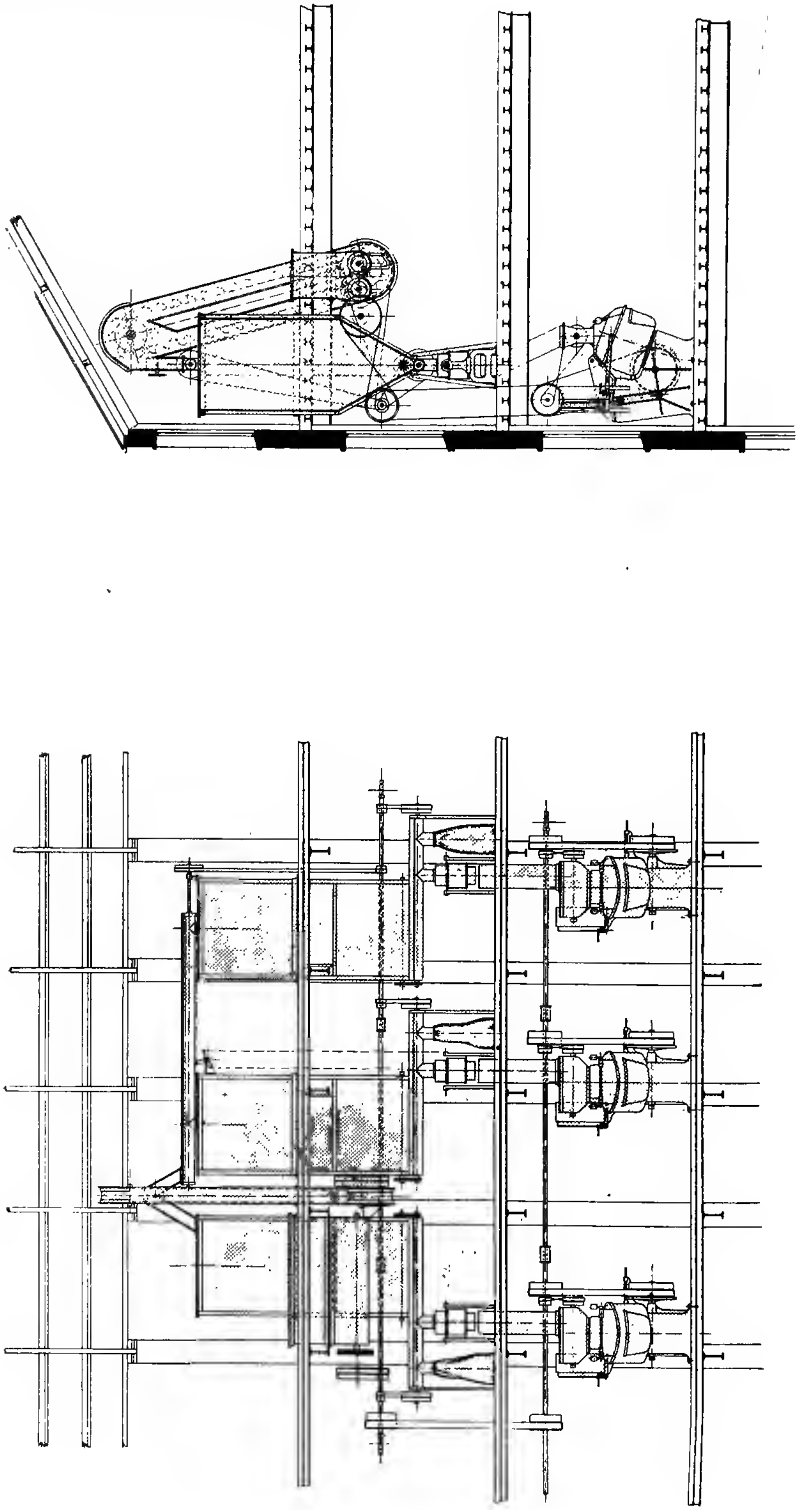


Fig. 39.—Special Flour Blending Arrangement.

PLAN X. Flour Blending Plant.



574. Blending Plant for Large Bakery.—There is no compromise possible for the large bakery that requires a blending plant. An elaborate and somewhat expensive installation alone will serve the purpose, and headroom is necessary to avoid objectionable conveyors. Plate X shows a plant for storing three blended mixtures of flour which can then be used at will; but owing to limited height a conveyor is employed for distributing the flour to the storage hoppers. The same plant may be so arranged that by the partial raising of the roof inclined shoots replace the conveyors. This second arrangement reduces the use of conveyors to a minimum; they are only employed for discharging the flour from the hoppers to the automatic weighers, and so do a minimum of harm.

575. Blending for Small Machine Bakeries.—An excellent plan, which reduces the outlay for machinery to a minimum, is to substitute a hopper feeding direct into the elevator for the blender described in the arrangement last mentioned. Pen boards placed in the hopper divide the same into compartments for receiving each one quality of flour. When the hopper is filled the pen boards are withdrawn and the elevator started, causing approximately equal proportions of the various flours forming the blend to be elevated to the sifter. If the kneader is allowed to run for a few moments previous to introducing the liquor, etc., a perfect blend is obtained. Ample time is allowed for obtaining the necessary output per hour of dough if the kneader is of a sufficient size. It will be seen that this arrangement has the further considerable advantage, that an ideal working scheme can be obtained with only two floors. The ground floor will be equipped with ovens, divider, etc., and the first floor with kneader, sifter, and elevator. The first floor therefore serves as doughing-room as well as flour store, and enables the cost of building to be kept at a very reasonable figure. In view of the considerable cost of a fully automatic plant and the relatively small advantage obtained by the use of the same, in comparison with the very simple arrangement last described, the authors recommend the latter except for really large installations. The photographic view (Fig. 39) subjoined, illustrates this arrangement very well.

576. Flour-Sifting Machinery.—Although many attempts have been made to introduce a sifter with reciprocating sieve or sieves, the rotary machine is the least troublesome and answers all practical requirements. The fact is that the reciprocating sieve, although theoretically the ideal arrangement, is in practice a nuisance because it cannot be made so as to

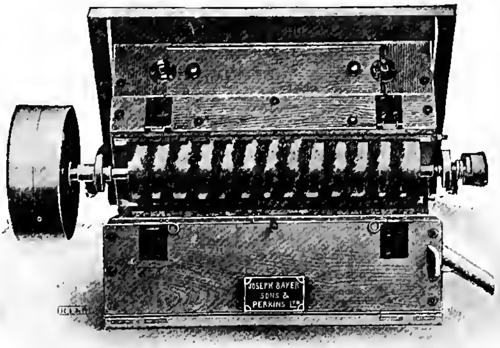


Fig. 40.—Rotary Flour Sifter.

be either noiseless or really durable. On the other hand the rotary sifter is not only quite noiseless and perfectly trustworthy, but from a commercial point of view does its work perfectly. The illustration (Fig. 40) shows a machine with a spiral brush roller working against a semi-circular sieve, which is contained in the lower box-like extension of the machine.

577. Tempering and Measuring Water.—The introduction of machinery in general, and of automatic bread-making plants in particular, calls for more accurate methods in the bakery than were formerly considered necessary. So long as doughs were made by hand the operative was more or less a craftsman, who could judge by touch and appearance as to whether the dough was of the correct consistency or not. The craftsmen are getting fewer every year, and in any case cannot be relied upon for sufficiently accurate judgment to suit modern requirements. In addition, however skilful the workman, he has in modern machinery no opportunity of controlling the consistency of his dough, other than by accurately weighing and measuring the materials; therefore if bread is to be satisfactory and uniform, if automatic dividers, provers, and moulders, are to yield the best results, and ovens are to soak the bread properly in a given number of minutes at a predetermined temperature, it follows that the doughs must be perfectly uniform. If they are not so, the results are either not of the best, or the smooth working of the bakery must be disturbed by allowing batches to have different periods for proving and baking. Clearly, then, too much care cannot be exercised in the making of dough. This subject will subsequently receive further consideration (see paragraphs 578-581); it is sufficient for the present purpose to say that an appliance is necessary, which will enable an exact quantity of water at a prearranged temperature to be accurately and readily obtained. Needless to say, the arrangements should also be such as to enable this result to be obtained without unnecessary waste of water in adjusting the temperature desired. Theoretically, much might be said in favour of weighing the water, as the most accurate way to obtain a given quantity. In practice, appliances for weighing introduce many complications of an undesirable nature, and are liable to derangement, leading to greater inaccuracies than simpler apparatus involves. The best and most practical arrangement is the tempering or attemperating and measuring tank here illustrated (Fig. 41). It is a tank formed of steel sheets, tinned inside, and supported on the wall adjacent to

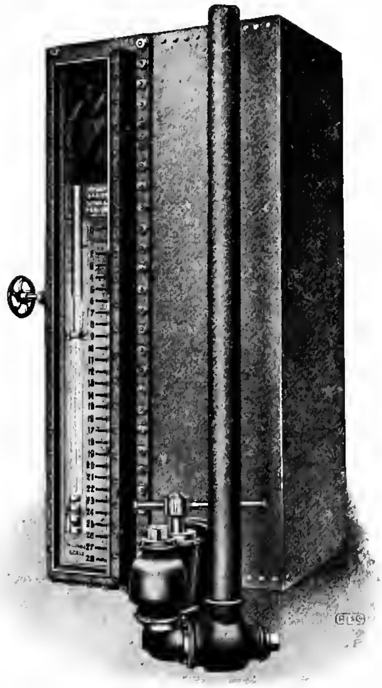


Fig. 41.—Tempering and Measuring Tank.

the kneader, or on the kneader itself. Hot and cold water are conveyed thereto in large bore pipes to prevent delay. The hot-water pipe is internally taken to the bottom of the tank, and the cold-water pipe discharges at the top. Thus an excellent mixing is obtained by the aid of natural laws, but, as an extra, a mixing paddle can be fixed with a vertical spindle—this hastens and perfects the process of obtaining a tank full of water at a uniform temperature, as ascertained by a thermometer which is immersed, completely and readily visible through the plate-glass front of the tank.

An internal overflow pipe is fitted and wherever possible (in all new bakeries, for instance) a sink or gully should be provided immediately below the position which a tank is to occupy. This gully will not only take such overflow from the tank as occurs, but is useful for washing down the floor, the kneader, and for emptying pails, etc. The specially useful feature about the tank illustrated is the sliding scale (Williams' patent) seen through the glass front, and readily raised and lowered by means of the hand-wheel on the left. This scale is plainly marked in gallons, as seen in the illustration, and facilitates the drawing off of the exact quantity of water required. In any ordinary tank it is practically impossible to obtain a pre-arranged level of the water, while tempering the same to say 96° F., without permitting an overflow, and thereby incurring a waste of water. The tank illustrated, however, is larger than the maximum capacity registered on the scale, and therefore allows sufficient margin for obtaining the correct degree of heat without overflow or waste. As soon as the water is at the right temperature and thoroughly mixed, which is indicated by the thermometer reading remaining stationary, the scale is moved to the position in which the zero mark exactly corresponds to the level of the water. The universally-jointed pipe, shown in an upright position in the illustration, is next placed in position to discharge the water into the kneader, and then the large draw-off shown is opened. As the water runs out of the tank and the level sinks, it is clear that the cock merely requires to be closed sharply when the water level has sunk to the mark indicating the desired number of gallons, to ensure that the right quantity of water, at the correct temperature, has been delivered into the kneader. These tanks are made in various sizes to correspond to the capacity of the kneader.

Attention is here drawn to the fact that certain waters (notably some moor waters) corrode iron and steel, even when protected by galvanising. To meet such cases these tanks are also made of copper and gun-metal throughout, coated with tin internally. These tanks are so cleanly and useful in saving time and ensuring better and more uniform results, that their employment, even in hand-worked bakeries, must be recommended. It is quite a common error to suppose that they are useful only in connection with machinery.

578. Dough Mixers and Kneading Machines.—Of modern dough-making machines there are three principal types which require to be considered in detail and which practically cover the entire field. The first group embraces machines constructed upon the principle of a revolving drum, the second employs a stationary trough with blades revolving around their own axes, and the third, arms moving in fixed planes in a revolving pan.

579. Rotary Mixers.—The idea underlying a rotary mixer is extremely simple. A drum, of a volume considerably greater than the size of the batch to be made, is revolved around a horizontal axle, which runs through the drum. Parallel to the axle are placed a number of metal rods which pass from one side of the drum to the other. A square opening is cut in the cylindrical sheet, which forms the drum and joins up the two circular castings, which constitute the sides; the opening is closed by a removable door. In revolving, the flour, water, etc., are tumbled about and over the bars until the dough is made. The door is then removed and the drum is revolved, until the opening is at the lowest point and the dough allowed to discharge itself. It will be seen that the machine is of a simple nature, does not require much power, and can be made very cheaply. But there its advantages end, and it is necessary to say that while its simplicity and inexpensiveness are attractive, the dough it makes is not kneaded at all in the proper sense, and lacks texture, volume and colour, while being wet, sticky and inclined to be lumpy when discharged. It follows that while the machine may answer for slack doughs, it cannot be recommended for those of a stiffer nature or for high-class work, or for obtaining a maximum yield. An impartial trial, with precisely similar flour and other types of machine, will prove this.

The rotary kneader was first put upon the market under the "Adair" patents.

580. Kneading Machines with Revolving Blades.—The construction of these machines is based upon the employment of a cylindrical trough which encases a revolving blade, with the axes of the two coinciding. The sheet which forms the trough does not complete the circumference, but merges above into a rectangular hopper, open at the top. In most machines two cylinders are employed with parallel axes, apart from one another by a distance rather less than the diameter of each cylinder. In exceptional cases three blades are employed, but the arrangement introduces undesirable complications and possesses no advantages *per se*. In the earliest machines, and many others, the blades were of a haphazard and of a more or less fanciful design, and although they all made and make dough, yet the problem of the shape of the blades does not seem to have been worked out on scientific lines.

The Two-bladed Kneader may be safely considered the most typical and widely-used dough-making machine employed in bakeries, and as such requires to be dealt with more fully. The best example of these is that known as the "Universal" (Pfleiderer's patent). In its original form, this was the first machine to be efficiently manufactured and introduced to the bakery trade. It is also generally acknowledged to be the most successful, except only for certain special types of dough. Of this machine an illustration is given in Fig. 42, showing the machine

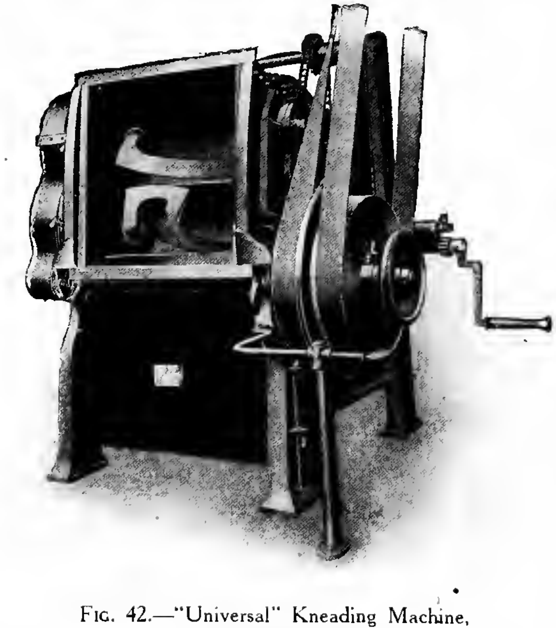


FIG. 42.—"Universal" Kneading Machine, Pfleiderer's Patent.

nearly tilted over for discharging the dough. The main secret of the success of this machine lies in the form of the blades, which are constructed on highly scientific lines, and ensure that every particle of the contents of the trough is brought within their action with absolute thoroughness. A small model machine on the same lines is sold by the makers, which constitutes a most useful addition to laboratories generally, where it is invaluable in many ways, apart from its utility as a dough-maker for small test batches. This little machine demonstrates the perfect mixing action very effectively, if it be charged with dry flour, and a pinch of red lead. With a stated number of revolutions it will so thoroughly incorporate the two ingredients, which by other means are not at all easy to mix intimately on account of the great difference in specific gravity, that a small part of the mixture, placed on a sheet of paper, will successfully stand the severe test of being "smeared" with a palette knife to prove the uniformity of mixing obtained.

Returning to the dough kneader, the next point to be mentioned lies in the arrangements for preventing the escape of liquid from the trough and for making the entering of grease or dirt impossible. The problem is not an easy one, but has been solved very simply and effectively. There are only six bearings in this machine, apart from the two loose pulleys in connection with the driving gear, and all are fitted with Stauffer solid grease lubricators. The drive is arranged to be reversible by means of friction clutches formed between each of the two pulleys and the central driving disc, which is enlarged in diameter and fitted with a handy rim to enable the machine to be pulled round by hand when being cleaned.

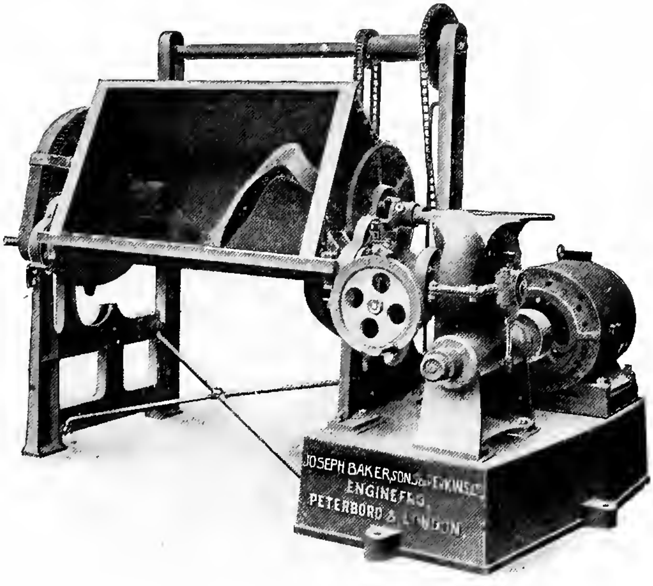


FIG. 43.—"Universal" Kneading Machine, Single Blade, Fitted with Electric Motor.

The control is from the hand-wheel overhanging the pulleys, which are driven in opposite directions by belts from the line shaft, one "open" and one "crossed," thus enabling the blades to be driven in either direction. The weight of the trough is balanced by counterweights, and the raising or lowering may be by hand or power as desired. The interior of the trough as well as the surface of the blades are ground and polished, and the dough leaves these surfaces perfectly clean, on being turned out, except with very slack doughs.

The machine is fitted, if desired, for driving direct by electric motor, which is then supplied with a reversing controller to enable the machine to be reversed. Fig. 43 shows a single-blade "Universal" fitted with a motor direct. This machine is made with pulley drive also, or the machine shown in Fig. 42 can also be fitted, self-contained, with electric motor as here shown (Fig. 44). To prevent the raising of flour dust, which would result from working the machines without a lid, these kneaders are either fitted with a sleeve and connected direct to the sifter, or they can be supplied with a "safety" lid, which is so interlocked with the driving gear that it is impossible to raise the lid while the machine is in operation. In certain countries these "safety" lids are made compulsory, as a prevention for accidents to operatives.

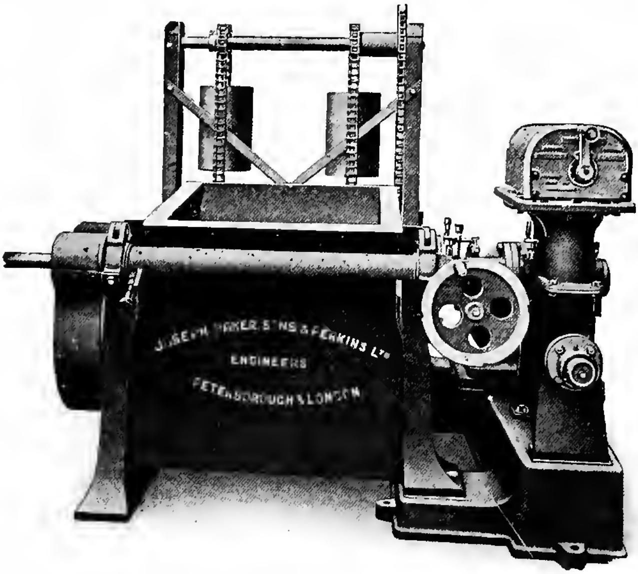


FIG. 44.—"Universal" Kneading Machine Fitted with Electric Motor.

581. Kneaders with Rotating Pans.—These are a comparatively modern product; many are of too light a construction to be serviceable, and have the serious defect that working parts requiring lubrication are to be found over the dough, on which grounds their use cannot be recommended. These machines employ a different principle altogether to those already described, and rely upon the stickiness and plastic and tenacious qualities of dough for their action, which may perhaps be described as more akin to sugar "pulling" than anything else.

Fig. 45 shows a diagram of the "Viennara" kneader ("Pointon's" patent). The arm is fitted with double horns, as shown in Fig. 46, and describes a curve, which compels the horns to move in a path shown in dotted lines (Fig. 45). The gearing is so arranged that the speed throughout this curve is not constant; it is slowest when the horns are descending and increases rapidly as the horns sweep the radius between the bottom and side of the pan, being at its greatest during the upward movement. The pan slowly revolves (about 4½ revolutions per minute), and being filled with flour to the line indicated, brings fresh material under the influence of the arm at each stroke (26 per minute). The effect

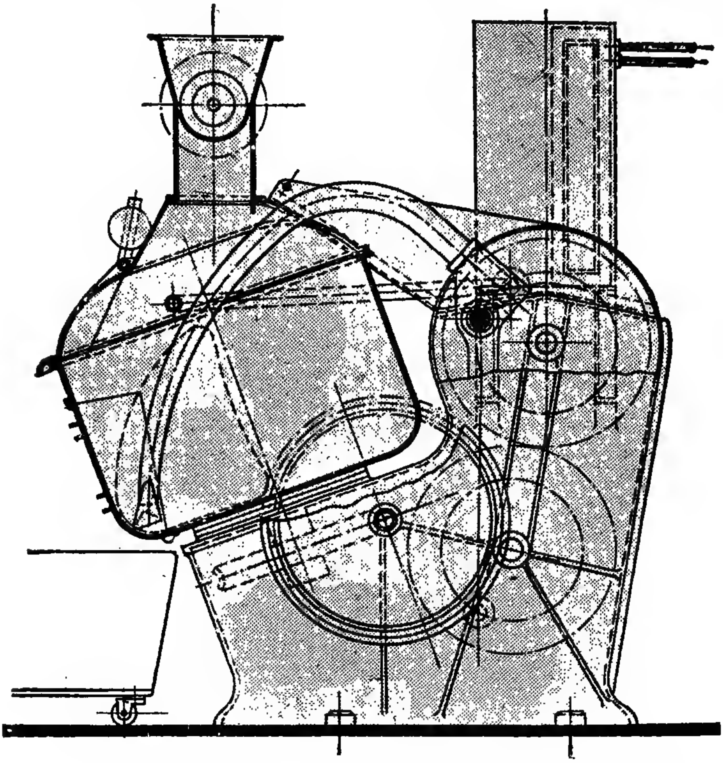


FIG. 45.—"Viennara" Kneading Machine. Sectional Diagram.

is to subject the dough, when incorporated, to a combined aërating stretching and folding action, most admirably adapted to develop it under ideal conditions and to an extent quite impossible by manual labour. The operation of the arm is of the gentlest kind, and owing to the perfectly combined aërating folding and stretching which the dough receives, it is of a remarkably fine texture, toughness, colour, and volume. Many claims have been made for devices for increasing the yield, a point on which bakers have become rightly sceptical; but certainly the "Viennara" has remarkable properties in the direction of causing the flour to absorb its proper proportion of water without loss of stiffness or elasticity. Consequently, the dough produced shows a decided improvement in colour.

Fig. 46 shows the complete machine with sifter and tempering tank self-contained. As will be seen, a door is fitted in the pan, which can only be stopped in the correct position for discharging. This door is interlocked with the driving control in such a manner as to make any mistake impossible. The dough truck runs under the pan, and the dough is discharged automatically by the arm alone being worked, while the pan remains stationary. The domed lid is a fixture, but the front portion is hinged and can be raised so that the dough can be inspected. The pan, having no blades, bearings or axles, has a perfectly smooth interior; it is therefore hygienically perfect and practically keeps itself clean.

In conclusion two important subsidiary advantages in the "Viennara" machine must be referred to. The first is that owing to the extremely gentle action of the machine, the arm of which can in no wise damage the dough more than a man's arm does in kneading, it is practically impossible to overwork a batch. Men will leave their jobs and cannot be relied upon to do exactly as they are told; it is therefore distinctly an advantage in this machine that by being left longer at work than is necessary it cannot damage—but will, in fact, rather improve, the dough. The second point needing a special reference is that, unlike other machines, this is a very safe appliance, in using which it is scarcely possible for a man to receive injury. The arm on its upward stroke will push out a man's hand, and can never pull him in if he attempts to feel the dough, as is only too frequently done.

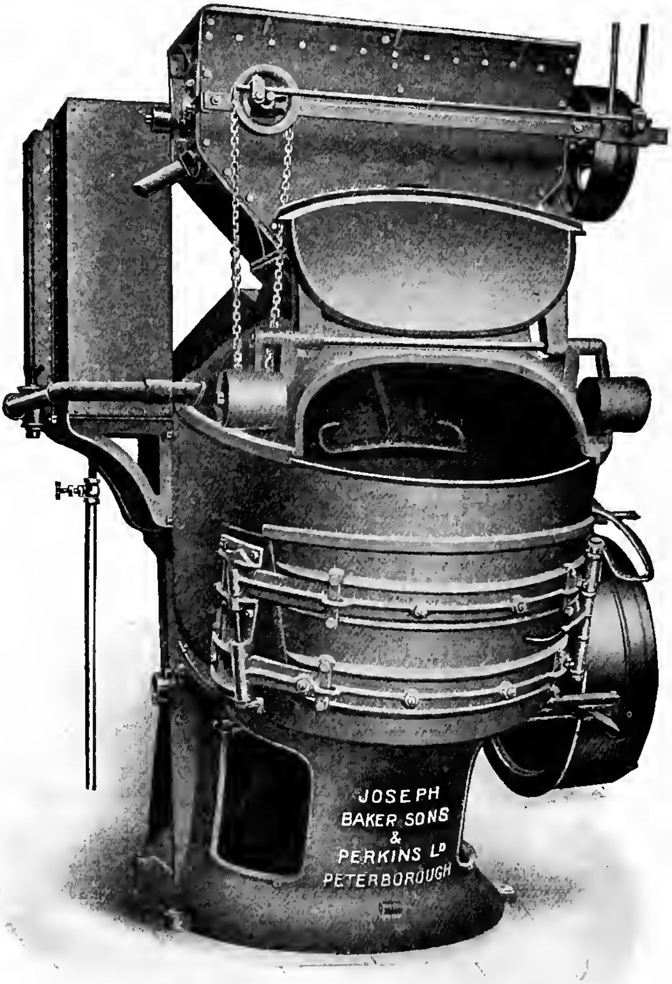


Fig. 46.—"Viennara" Kneading Machine.

582. Sponge-making Machines.—Before leaving the subject of kneaders it is necessary to describe the application of such machines to the making of "sponges." Although the tendency in machine bakeries has been for many years to adopt the "straight dough" system, dispensing with sponges and kneading the flour with yeast and salt into a dough direct, yet the older process holds its own in many countries, and also in portions of the United Kingdom, notably in Scotland and Ireland. A very convenient combination is provided by the "Universal" machine already described, when such a machine is fitted with two speeds to be used at will. It will be clear that this enables a high speed action to be used for making light sponges, which when made are turned out into dough trucks and left to prove. These sponges when ready are then utilised for making the dough, for which the second or normal slow speed of the kneader is used.

583. Sponge-Stirrer.—Another form of machine frequently used is the sponge-stirrer, of which an illustration is given in Fig. 47. A cast-iron standard carries the driving gear as well as the upright spindle fitted with suitable blades, which being balanced and arranged to be conveniently raised, permits the tub, fitted with casters, to be readily placed in position. The sliding casting, shown in the illustration above the stirrer proper, rises and falls with the latter, and acts as a self-centring guide to the tub, which is automatically locked in position as soon as the spindle has been lowered. A sifter is fixed above the stirrer (as shown) and, by means of a canvas shoot enables the flour to pass direct into the tub. The illustration also shows the kneader, with sifter and tempering

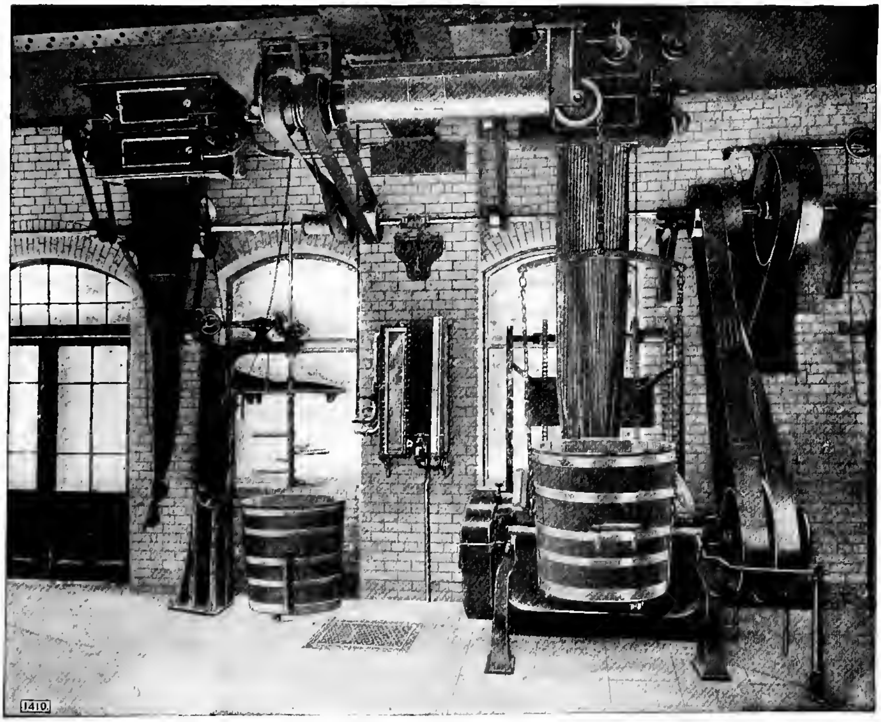


FIG. 47.—Sponge-Stirring Machines.

tank and the tub lift, with a tub lifted ready for discharging its contents into the kneader, thus giving a very clear idea of the whole installation for suitably dealing with doughs in such bakeries as employ the "sponging" process.

584. Dough Trucks and Dough Proving.—As has been already pointed out in paragraphs 546 to 554 dough trucks should always be movable. They should therefore be of a "handy" size, never exceeding a capacity for two sacks. They should be fitted with casters, or if preferred with one caster at each end and an axle in the centre, with two loose wheels, designed to take the whole load and keep the casters just off the floor. In England the dough trucks are almost universally of wood. It is difficult to account for the prejudice, which tenaciously clings to British practice, against the employment of metal in this connection, despite the fact that in all other matters pertaining to bakery equipment, especially as regards large establishments, this country is undoubtedly ahead of all others. The common idea is that the metal trough must chill the dough, but as the dough will be chilled in any case if the bakehouse cold—and the truck cannot be cold if the bakery is not—the conclusion is not very logical. Further, the specific heat of iron is low, and the trough cannot under any ordinary circumstances, affect the temperature of the dough to a material extent. As a matter of fact the wooden dough truck has practically disappeared from all modern plants on the Continent, and as the Continental baker appreciates the importance of not chilling his dough, at least as much as his British confrère, the statement that there is no objection to the use of iron or steel in dough trucks, any more than in kneaders, dividers or moulders, must be held to be proved correct. Of course every baker will please his own tastes in such a matter as this, but it is at least worth while to point out that the not inconsiderable wear and tear, with consequent renewals, occasioned by the use of wooden trucks, may be eliminated by the employment of the very much more hygienic

FIG. 48.—Steel Dough Truck.

and durable steel truck, with bright ground interior surface, similar to that of a kneader. A good plan is to use steel troughs tinned inside, as being the most suitable surface. An illustration (Fig. 48) is given of such a trough showing its general construction.

The dimensions of trucks should be suitable for the machines with which they are to be used, a point sometimes overlooked, and both width and depth should not be too great, as unduly heavy work is otherwise thrown upon the operative. Inside dimensions of about 2 ft. in width and 1 ft. 6 in. in depth should not be exceeded.

585. **Proving-Rooms.**—When bread was almost universally made by the long sponge system, the employment of separate rooms, kept at an even temperature, for the storage of sponges during fermentation, was always regarded as a great advantage. With the advent of automatic plants, the subject requires consideration in a new light. The fact is that separate proving-rooms may be responsible for bad results, where automatic plants are in use, unless steps are taken to ensure that the temperature of such rooms does not vary from that of the machines. Now it cannot be sufficiently insisted upon that dough must not be subjected to changes of temperature throughout its different phases; and, when ready for dividing (scaling), should not be brought into rooms, or fed into machines, which are at a different temperature than the dough itself. It follows that the arrangement of the bakery should be such as to make this automatic if possible, because the more it is left to the men to observe such matters and regulate temperatures the more trouble will ensue. The machine-room, and therefore the machines contained therein, should be kept at a uniform temperature, equal to that of the doughing and proving-room, and all should of course be arranged so that they are free from draughts. If this cardinal principle is adopted and never lost sight of, and if new bakeries are designed with this clearly in view, much trouble and constant watching will be saved. Assuming a bakery perfect in this respect and equipped with automatic plant of the best type, a wonderfully high and uniform standard of bread will be obtained, if reasonable care be used in preparing the doughs at the proper and uniform temperature.

586. **Dough Dividers.**—These were first placed upon the market in a commercially practicable form about the year 1896. The introduction of loaf dough-dividing machinery marks a distinct and very far-reaching development in the mechanical equipment of bakeries. All subsequent stages of dough-making and machine-working, however difficult of solution in themselves, are dependent upon, and secondary to, the problem of satisfactorily weighing off pieces of dough of given weights from the bulk. In the course of the last fifteen years three main principles have been employed in the construction of dividers. Cylinders or boxes with close-fitting rams, the latter adjustable to give variable volumes provided to receive the dough necessary to form one piece or loaf, are common to all three types referred to. It is in the means employed for charging these cylinders or boxes with dough that the three types principally and materially differ. A worm, acting as a conveyor at the base of a dough hopper—fluted or roughened rollers running in opposite directions, charging a chamber, communicating with the cylinders—and a weighted ram acting upon the dough confined in a closed chamber, are the three different means referred to. All three principles lend themselves to the construction of machines capable of cutting dough pieces, with sufficient accuracy for all commercial purposes; in fact to the production of loaves

of much more uniform and accurate weight than is commercially obtainable by hand. The effect of such machines upon the dough, and upon the process of fermentation, is, however, the chief consideration and requires to be most carefully taken into account. Dough is not a material which may be ill-treated with impunity; it is, or should be, a living mass which may suffer irretrievable damage if handled with a trifling excess over the permissible severity. This aspect of the matter is often dismissed with unpardonable levity, on the plea that "a little more yeast will soon put that right," or that "it can be left a little longer to recover"! There is no such thing as artificially counteracting actual damage, either by an extra allowance of yeast or reviving fermentation, which has unduly suffered, by allowing extra proof. These are palliatives and may mend, to some extent, the worst effects of undue severity, but cannot and do not allow a healthy growth or perfect development to take place.

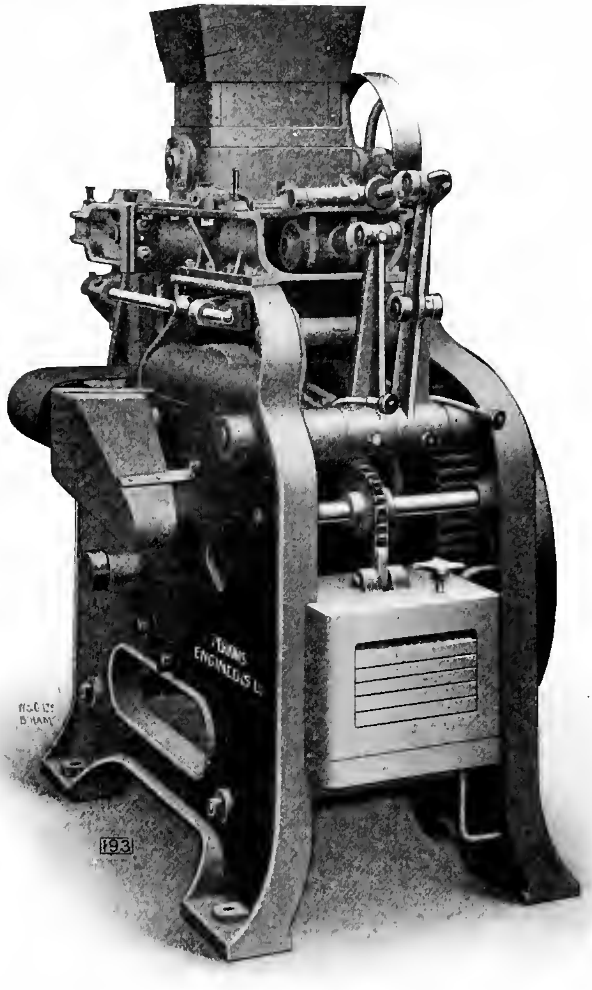


Fig. 49.—Two-Cylinder Dough Dividing Machine.

In two of the systems quoted above there is the inherent drawback that the force put into the dough (or force with which the dough is handled) cannot be definitely limited in such a manner as to preclude damage. The action is not positive, and therefore always employs a surplus of feeding capacity to ensure the filling of the cylinders, which by their regulated volume give the weights required. On the other hand, the third type absolutely limits the force employed and is positive in its action. The pressure to which the dough is subjected by the ram which causes it to enter the division boxes can never exceed a safe and predetermined maximum, since it is due to a weight which in working remains constant but can be varied to suit the requirements of the class of dough used, and never forces forward a greater quantity than the measuring cylinders absorb. It follows that the maximum advantage, when using a machine of this type, will be obtained by employing a minimum weight to give sufficiently accurate loaves.

Correct Weights.—It will be opportune, at this point, to call attention to the relative value of weighings, more or less accurate. It is a fact that it is possible to insist upon too much accuracy, especially in view of the very natural tendency to scale as closely as possible and obtain the maximum saving in dough. Everything, however, may be carried to excess, and a baker may easily lose more in quality, and therefore in texture, bulk, and general attractiveness of loaf, than he gains in dough by very close weighing.

Extreme accuracy is inseparable from punishment, and in turn punishment is inseparable from loss in legitimate selling qualities of the loaf. So long as a divider gives more accurate weighings than can be commercially obtained by hand-scaling, a business will be more benefited by good quality, due to avoidance of punishment, than from an insistence on the maximum economy in dough.

The sound plan therefore is to choose the divider which is limited in its punishing effects, and then adjust the machine to work with the minimum weight required to ensure sufficient accuracy for commercial purposes.

The illustration (Fig. 49) shows a two-cylinder deadweight divider, suitable for small bakeries, which has a maximum output of 1,400 pieces per hour. For guidance as to proper proportions of output, remunerativeness, etc., see paragraphs 555 and 557. Larger machines, with outputs up to 2,400 and 3,600 pieces per hour, are referred to in paragraph 594 under Automatic Plants. Both machines are made right and left handed for belt, or direct electrical, driving.

587. Moulding Machines.—When the newly-kneaded dough is turned out into the dough truck, it requires to be left undisturbed at a proper temperature in order to ferment, and as a result of the generation of gases the original volume of the dough is much increased. It is here that the value of a good kneading machine becomes apparent, because if thorough aëration has been combined with a maximum of stretching and folding, the result will be a dough which excels in bulk, toughness, fineness of texture, and good colour.

To obtain the best results it is essential for the development of fermentation to be as uniform throughout the whole mass of dough as possible, and for the gluten to be toughened, so as to resist the gases uniformly, causing an evenness and silkiness of texture not otherwise obtainable. Judicious and efficient "cutting back" assists uniformity for the same reason, and when finally ready for scaling or dividing a good dough must be uniform all over. It will be apparent that in cutting the dough, when scaling or dividing into pieces of a size suitable for loaves, these conditions are disturbed, inasmuch as fermentation will, from that moment, take place under totally different circumstances. Apart from this, the cutting produces wounds, which form portions of the surfaces of the piece intended to become a loaf. It is therefore necessary to re-work each piece, with the two-fold object of closing the wound by forming a complete skin all over the dough-piece, and of working the interior, so as to cause fermentation to continue under conditions which will be uniform and suitable throughout the newly detached piece of dough intended to become a loaf. This process is called moulding.

Hand Moulding has hitherto been performed in such a manner that the piece was rolled on a table, against the palm of the hand, as a more or less pear-shaped mass, causing the central portions to be worked outwards, and *vice versa.* It was essential to preserve the skin, which was formed in this process, from rupture while tightening up the interior, which of course had the effect of stretching the skin simultaneously. The tail of the loaf, similar to the gradually contracting and tube-like lower extremity of an inflated balloon, sealed the skin and was worked into the loaf-piece at the conclusion of the operation, when each piece should become as nearly spherical as possible. The loaf was placed tail downwards on boards or in drawers to undergo a further period of proving, protected from chills. It is needless to say that good moulding could only be performed by a craftsman, and that the quality of workmanship varied to a very great extent. The labour was monotonous, and also arduous, if carried on indefinitely, while effective supervision and a maximum speed were not easily obtained. From a hygienic point of view also it was objectionable.

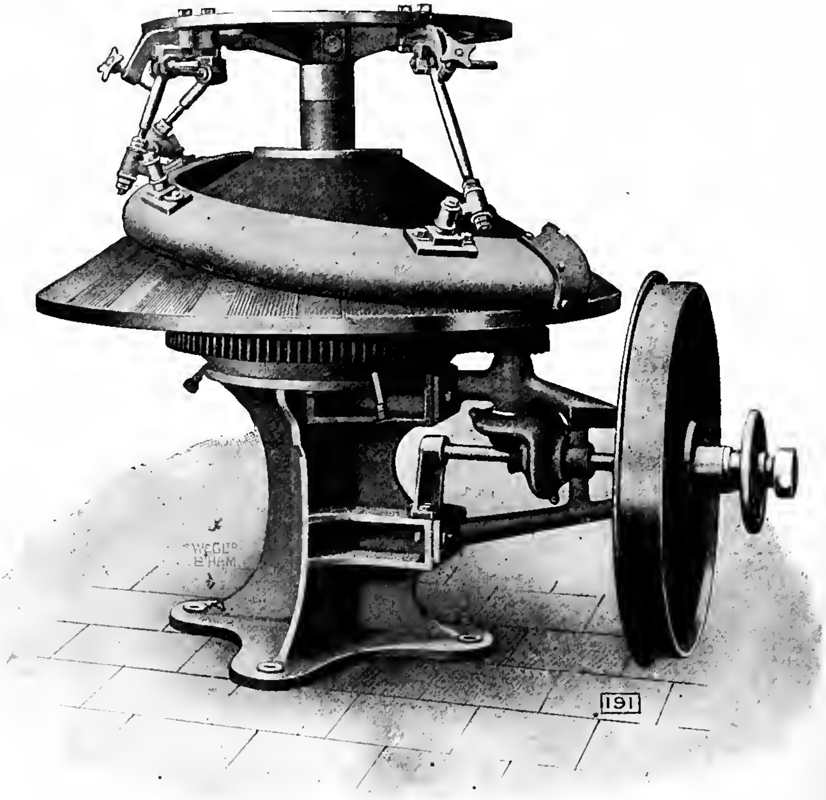


Fig. 50.—Dough Moulding Machine.

Machine Moulding.—To find a satisfactory solution of the difficult problem of moulding dough by mechanical methods proved by no means easy. The experience of several years' working, however, conclusively shows that the task has been accomplished. The principle adopted is to impart to the dough-piece a continuous, rotatory, and screw-like motion ("Pointon's" patent) by feeding it into a spirally shaped trough arranged upon a revolving cone-shaped table (see Fig. 50).

The spiral trough is stationary, with its finished (ground) surface on its under or working side; it is supported by arm-rods, and brackets from above by means of the column, around which the table revolves. The table is grooved to afford grip to the dough. It is obvious that if the trough were merely arranged to encircle the table horizontally a pure rolling motion would be imparted to the loaf. A skin might thus be formed, although it would be wrinkled and not in any way stretched, but the dough itself would only be squeezed about and in no sense truly moulded. The illustration, however, shows that the trough, after a short horizontal length, to enable the dough-piece to start rolling, gradually ascends the cone table, causing the loaf to be forced against it. The result is that the dough-mass does, in fact, undergo a screw-like motion, systematically displacing and methodically rearranging the whole of its bulk, while stretching the skin continuously from the head of the loaf tailwards in every direction. At its upper or delivery end the trough again "eases off" its rate of mounting the conical table, and thus ceases to form the tail, which is "tucked in," and enables the finished loaf to roll off the table in as nearly a spherical condition as is necessary for all practical purposes. The proper accomplishment of this process is essential to the obtainment of *"build,"* ensuring not only a tough and highly stretched skin and a thoroughly worked interior to the loaf, but also that orderly and regular rearrangement of the cellular structure which, by means of proper subsequent proving, compels the growth of that much desired and beautiful texture of the perfectly developed loaf of bread.

From the description given, it will be seen that the "pitch" of the trough, which governs the rate at which it ascends the table, will regulate the degree of "working" imparted to the dough. If too much "working" is put into the dough, the skin of the loaf will be overstretched and yield under the strain; and if too little, then the "build" will not be sufficient. It is necessary also to point out that the capacity of the trough must be suitable approximately to the size of the loaf to be moulded. In consequence of these two important considerations a number of troughs are required for each such moulder, if various sizes of loaves—or if bread made from doughs of widely differing consistency—are required to be moulded. In practice the cone-table or "umbrella" moulder is now only employed in businesses with uniform outputs.

588. Flexible Moulder.—In order to provide a moulder which shall be capable of ready and instantaneous adaptation to all the varying requirements of average bakeries, the inventors of the previously-described machine have recently put upon the market an improved and perfected form, illustrated in Fig. 51, which they term the flexible moulder. The principle underlying the construction of this machine is exactly the same as that of the "umbrella" type. A flat moving table is formed by close-fitting metal laths connected by chains which constitutes an endless iron belt running over axles, whose axes are steeply inclined from the horizontal. The moulding troughs are thus enabled to be made perfectly straight and therefore adjustable for capacity by the simple and instantaneous movement of a single lever; they can consequently mould dough-pieces of widely differing weights, found in practice to vary from ¼ lb.

to 4 lb. pieces. Being suitably supported by bridges spanning the entire width of the moulding surface, the angularity of the troughs upon the table can also be adjusted at will, so that doughs of widely differing consistencies can be dealt with. This machine is provided with the following fittings—two parallel troughs, a "splitter," which cuts the 2 lb. piece of dough into suitably proportioned pieces for forming the "tops" and "bottoms" of cottage loaves, and a tin shaper for suitably shaping tin loaves to fit the particular "pans" in use. It may therefore be fairly claimed for this machine that it is universal in its scope, and solves all the requirements connected with the "balling up" type of moulding.

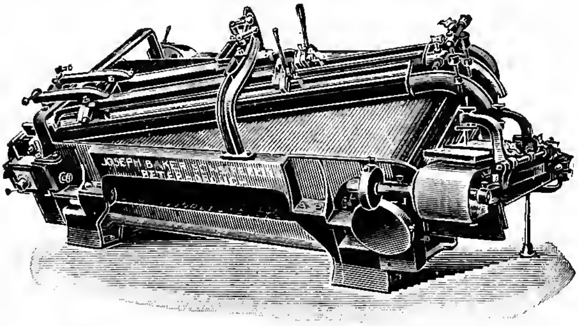


Fig. 51.—Flexible Moulding Machine.

589. Another Mode of Machine Moulding.—An alternative means to those described above has recently been introduced for giving a very complete stretching action without risk of damage to the dough, which is proving very successful on the very slack and sticky pan bread doughs of Northern England, made from exceedingly weak flour. It is the outcome of much experimenting, owing to the failure of the "rolling out" and "coiling" type of moulder to deal with slack doughs made from weak flour. This failure is due to the punishment inflicted upon the slack doughs from weak flours almost universally employed in Great Britain and prevents that full recovery of fermentation afterwards necessary for obtaining a really first class loaf.

The principle of the new method is that of using a fluted spindle, making a pre-determined number of revolutions for each loaf treated for coiling the dough-piece and thereby causing internal compression within it. The spindle speed requires to be suitable and the revolving piece of dough has applied to its outer surface suitable pressure by means of yielding rollers or bands to give just the compression required. On completion of the correct number of revolutions the spindle reciprocates rapidly in an axial direction, and thereby withdraws itself from the dough-piece, allowing the latter at once to fall clear. It is found that the mechanical "rounding up" or "moulding" of even the most delicate dough can by this means be performed with the very best results, and that the finest possible development of volume, texture, colour and flavour are secured.

The application of this principle to Automatic Bread Plants for rounding purposes takes place immediately after the dividing stage, and the rounders of this type are built essentially as an adjunct to the divider itself. The dough-pieces fall directly upon their discharge from the divider boxes on to the spindles of the rounder, and on their return from the spindles directly into the pockets of the prover trays. It follows that the number of division pockets, rounder spindles and prover tray pockets employed as one series are the same, the whole forming a continuously moving series of links in a chain of elements, ultimately delivering the loaves to the moulder.

In considering the actual work performed by each spindle it would not be correct to say that it stretches the dough into sheets in the classical manner of making up a pan loaf by hand, or that it then coils up the sheet thus obtained, but it does in fact perform an operation which yields an identical result in the finished loaf, since by another method it subjects the structure of the dough-piece to the treatment which is required to ensure uniformly even distribution of the gases, while putting the "interior" under compression within a suitable skin which is under tension.

In this as in all similar processes, it is not a question of reproducing mechanically a method which has established itself as the result of the exigencies of hand working, but of substituting therefor a process which lends itself to mechanical operations, while yielding the same or a better result.

590. **Quality of Machine-Moulding.**—It is perhaps natural that scepticism should be felt in regard to the degree of good workmanship attainable by such machinery as has been described, when the difficulty of getting good moulding by hand is borne in mind. Flexible moulders are of such recent introduction that the number of bakers who have as yet had the opportunity of seeing such machines at work is comparatively limited. For the guidance of those who may remain unconvinced, the authors' personal experience is that the machine above described will mould as well as the journeyman, with this important point in its favour —that it reaches the same standard of perfection with every single one of the 3,000 loaves which it is capable of turning out per hour. The journeyman's average workmanship will be much below the best he can do, but the flexible moulder will never fall below its best. Hence, moulding machinery should be carefully investigated on behalf of every progressive machine bakery.

591. **Handing-Up and Proving.**—If a loaf is moulded directly after having been scaled off it will lack development and cannot possibly be either of as good texture or bulk as it should be. It is therefore necessary to give each dough-piece a preliminary moulding after being scaled off, so that it may have a period of rest in which to recover or prove before being finally moulded into shape ready for baking. This preliminary process is called "handing-up" or "balling-up." The above remarks apply to ordinary hand-made bread, notwithstanding the fact that there are a good many bakeries, especially in certain districts, where the loaf is finally moulded directly after having been scaled or divided. When considering the question of machine-moulding, it is very necessary to appreciate

accurately the different conditions under which the dough is then handled. When hand-moulding is employed there is always a considerable number of dough-pieces on the table which have been scaled or divided; which means that there is always a short period of rest before moulding actually takes place. Slight as this rest may be, it is essential, and gives the dough an opportunity of recovery before being moulded. This it cannot possibly have if fed automatically from a divider into a moulder, as under such conditions the moulding takes place the instant the piece has been divided. In hand-working there is no reason why this accumulation of loaves and consequent rest should not be allowed to take place, as it involves no extra labour and is beneficial to the dough. With machinery, however, unless the divider feeds directly into the moulder, an additional man would be required to feed into that machine. The necessity for handing-up, although always present if a good loaf is required, is all the more pronounced in the case of machinery; excepting only in special cases such as with very slack tin doughs, which may go direct from the divider to the moulder with reasonably satisfactory results. It will be understood, however, that these remarks apply only to cases in which the aim is only an average quality of workmanship; there can be no doubt that, where a really good loaf is desired, handing-up is indispensable and remunerative. Assuming then that handing-up must be included as an essential operation in the process of making a good loaf, it becomes necessary, for businesses with an output sufficiently large to necessitate continuous running of machines during working hours, to instal two moulding machines for every divider.

592. Hander-Up.—The first of these machines is coupled direct to the divider and is called a hander-up. In principle, the hander-up is exactly similar to the moulder; but as the newly divided loaf is of smaller bulk than when it comes to be finally moulded and also requires less action put into it, the hander-up is a smaller machine than the finishing moulder. Businesses with outputs up to one-half the capacity of the divider installed, need not instal two moulders, but by employing a finishing moulder only may, by arranging for the machines to be worked intermittently, get as good and as economical work as the full equipment yields to the business with a large output. In either event, that is to say whether handing-up and moulding are done in separate machines or on a finishing moulder only, a period of rest, averaging about 20 minutes, is necessary between the two operations, and provision has to be made for proving the loaves under suitable conditions as to temperature and protection from draughts. To use any of the older devices in this connection, such as drawers or proving racks, etc., entails the separate handling of each loaf into and out of the accommodation provided, apart from the labour in feeding the loaves into the final moulder. It also involves possibilities of bad organisation and careless marshalling of the racks, while the men may not take the batches in their proper consecutive order and may thus give some less and others more than their proper period of proof. Considerable space for racks, etc., and for moving them about would be required.

593. Automatic Prover.—To obviate the foregoing objections and dispense with all labour between the hander-up and moulder, and ensure the best possible development of the loaf, the automatic prover has been introduced. This machine receives the loaves from the hander-up, and discharges them, fully proved, in perfect condition to the moulder; the whole process, from the feeding of the divider to the discharge of the finished loaf ready for the oven, thereby becomes perfectly automatic.

The auto prover ("Pointon's" patent) is essentially a conveyor suitably regulated as to speed (with provision to vary the latter if required) and thoroughly enclosed to exclude draughts. Further, it is capable of being heated, and in any event is supplied with moist vapour so as to prevent a dry skin from forming on the loaves, which are consequently proved under perfect conditions.

594. Auto-Dividing, Proving, and Moulding Plant.—Fig. 52 shows diagrammatic representations of two modifications of an entire plant of this description. The loaves coming from the divider fall direct into troughs on the hander-up and, having been "balled up," are deposited on trays (eight pieces on each tray, in the full size machine), which are carried on chains, traversing the interior of the prover by a circuitous course in such a manner as to effect as great a saving of floor space as height of ceiling and other circumstances permit. The trays move intermittently, and of course at a speed suitable to give the length of proof required, which normally is from 15 to 20 minutes. Stepped pulleys are provided for running these trays, so that the rate of speed can be controlled within certain limits. By the time a tray has travelled round the prover and has allowed the loaves deposited upon it from the hander-up to undergo the correct period of proof, it reaches a position directly over the delivery band and by engaging with a suitable gear is turned upside down, depositing its load of eight loaves on the delivery band. The latter, travelling out sideways, delivers the loaves singly on to a further conveyor which feeds them (in the case of cottage loaves through the splitter already referred to) into the finishing moulder.

The lower diagram in Fig. 52 shows a form of prover in which much greater variations in length of proof can be obtained at will. By convenient mechanical arrangements the long conveying band can be "short circuited" at desired points and the loaves at once passed direct to the finishing moulder.

The prover is so designed that it can be arranged in a variety of ways in order to suit varying local conditions. It normally occupies a floor space of about 12 ft. × 10 ft., but can be suspended under the ceiling to partly overhang the moulder; or it may be fixed, together with the hander-up and divider, on an upper floor and deliver to the moulder below. The best arrangement, however, to suit any given place must of necessity be decided in consultation with the engineers. On the face of matters it might be thought that a prover arranged under the ceiling would be best with a view to the saving of floor space thus effected, but as a matter of fact there are a number of serious objections to this plan, which should only be adopted in conjunction with proper safeguards to meet the following points. Every one, with experience of bakery working, well knows the difficulty of ensuring cleanliness in odd corners and inaccessible places. A prover, with its damp heat, is peculiarly liable to get into an insanitary condition, and thus calls for rigid cleanliness and scrupulous attention. Being, therefore, of all the machines employed in the bakery to-day the one most needing conscientious inspection, it is the last which should be so constructed as to render efficient daily examination difficult.

The prover, illustrated and described, thoroughly meets these requirements; it is fitted with large doors, so that it can be opened out every day, and thoroughly ventilated. Readily removable cloths are fitted to the trays, so that their frequent washing is facilitated. A permanently fitted light in the interior is recommended, so that it may be impossible for any part of it to get into an unhygienic and objectionable condition without instant detection.

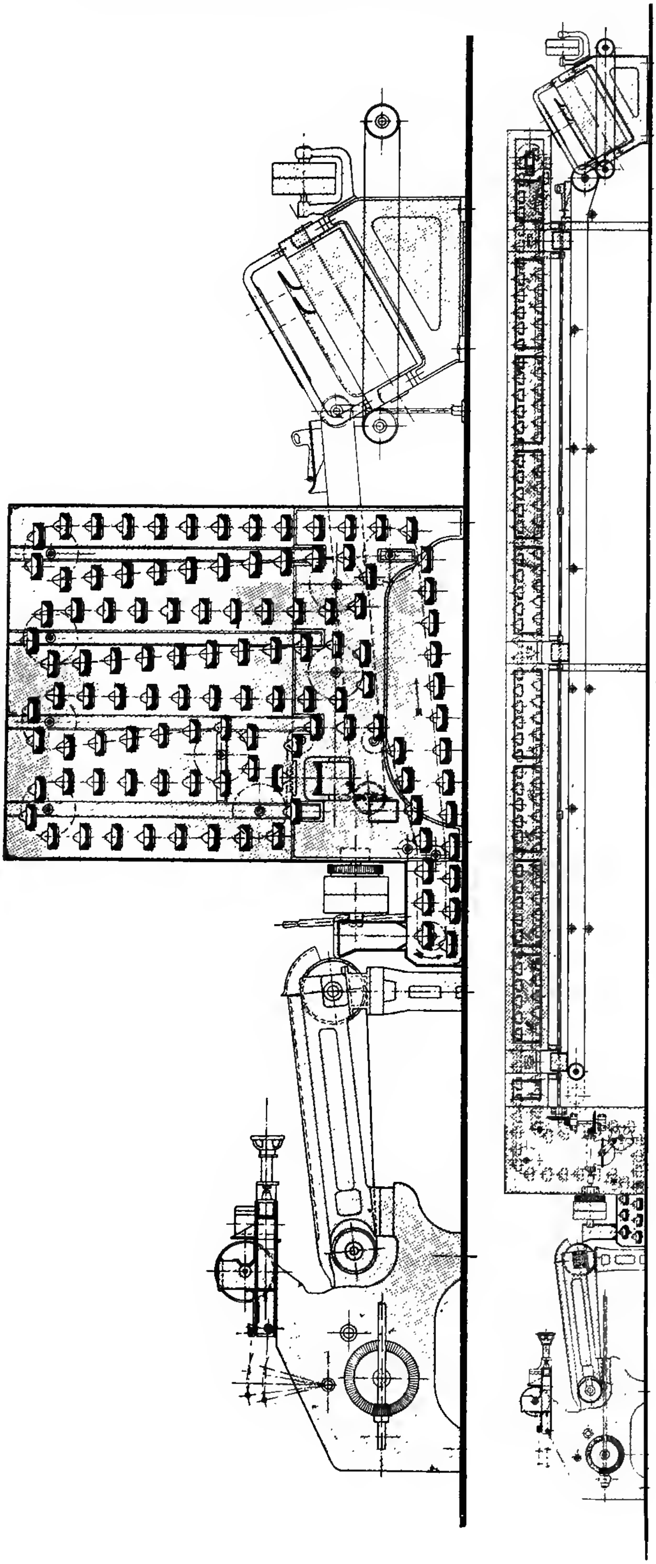


FIG. 52.—Diagrams of Automatic Plants.

The whole of the trays in the prover can be easily removed (they are only hung upon pegs) and should be periodically scrubbed. When the trays are removed, the interior of the prover can be entered and examined without difficulty—the reader may imagine himself standing in it, as in a small room. The result of five or six years' continuous working, in actual bakehouse use, is entirely satisfactory; it may therefore be safely stated that the apparatus is now entirely beyond the experimental stage. The prover is really free from any wear and tear, as the speed of the running parts is low, and the load on the trays is practically balanced.

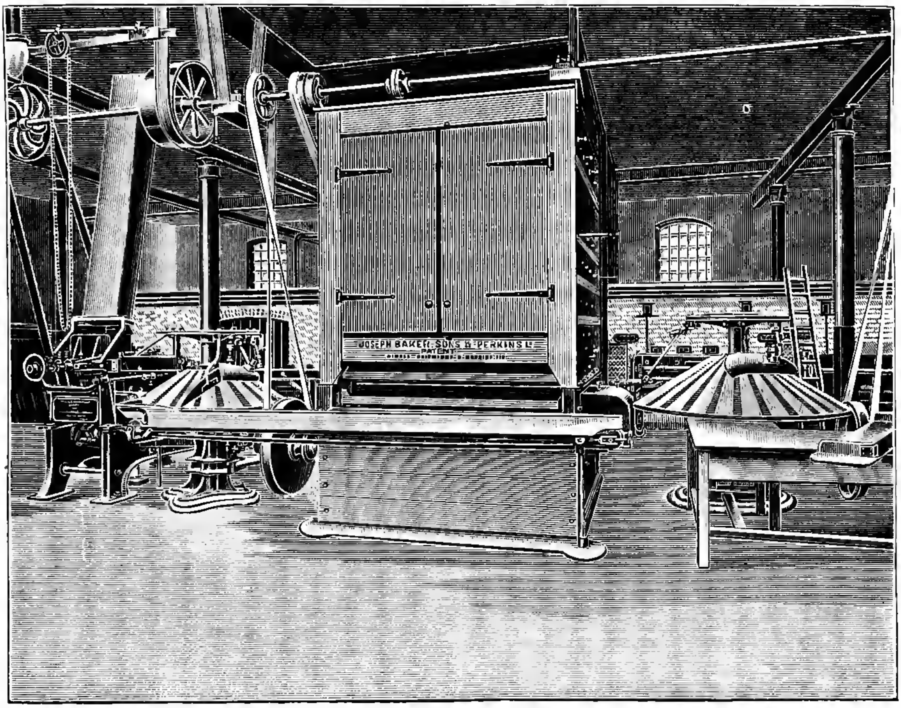


Fig. 53.—Semi-Automatic Plant.

The power required for driving the complete installation, consisting of dough divider, hander-up, auto prover and finishing moulder, is only about 8 h.p. The plant, when once installed, is therefore not expensive to run, since the whole of the operations indicated are carried out with one man for feeding the dough into the divider. When the dough has been thus fed, a maximum output of finished loaves from the moulder is obtained at the rate of 2,400 pieces per hour, in the case of a plant with a 4 cylinder divider, or 3,600 where a 6 cylinder divider is the primary unit. For bakeries requiring intermittent working a semi-auto plant is available, of which a view is shown in Fig. 53.

595. "Setters."—The appliances hitherto in use in modern bakeries for receiving the moulded loaves, and for conveying them to the ovens, in so far as they have been specially adapted at all, have all been modifications more or less of the type introduced in the early days of drawplate ovens under "Price's" patent. An upright framing, mounted centrally upon a bogie fitted with casters, carries rods or brackets projecting on either side. Upon these brackets rest trays, open upon one of the longer sides only. The loaves are set upon these trays, which fit the width of the drawplate, and are slid off upon the latter, as shown in the illustration, Fig. 54.

Cloths, fixed to the central upright of the setter rack, are spread over the loaves while proving. On another plan, the setter boards come close together, and with closed sides to the rack, are kept protected from draughts; the trays are then placed upon the rack with their open side inwards (see Fig. 55).

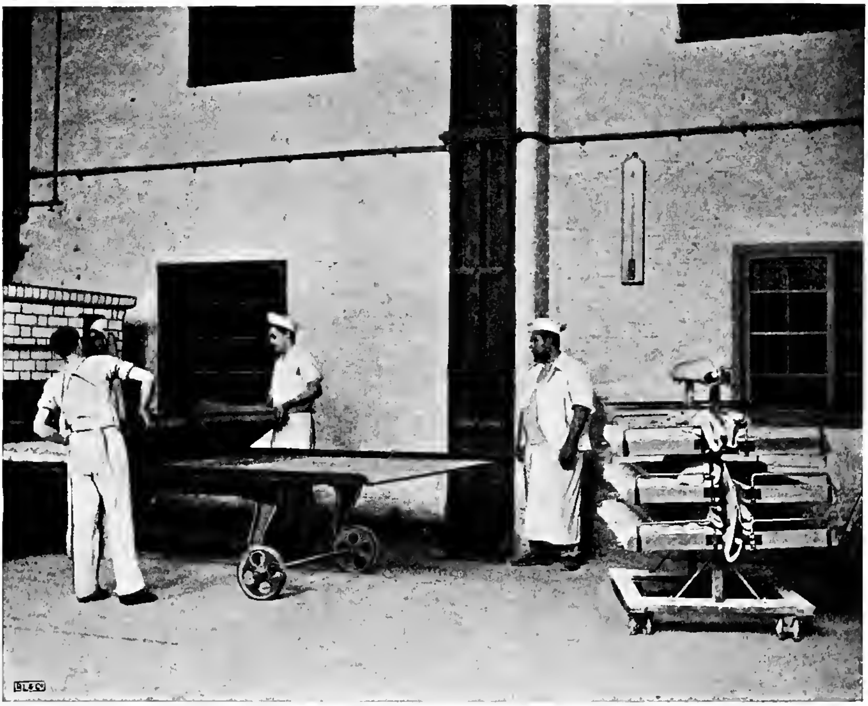


Fig. 54.—Loading Drawplate from Setter.

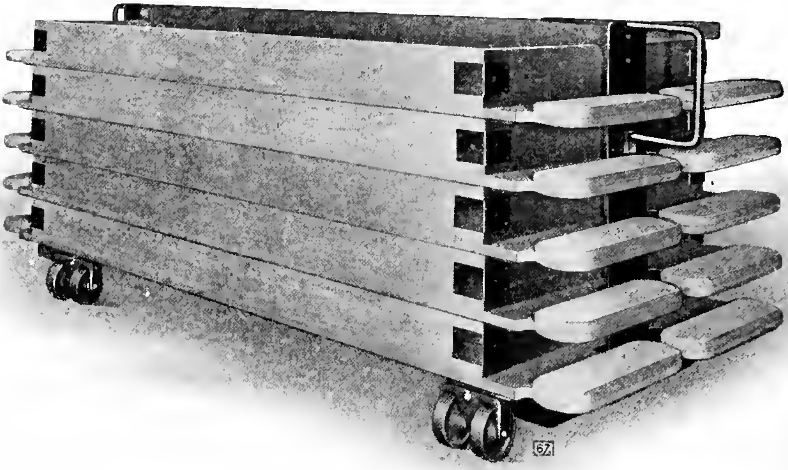


Fig. 55.—Improved Setter.

596. Final Prover.—Something more than the above is required, especially for dealing quite satisfactorily with cottage or other loaves that are made from two pieces, which are "topped," *i.e.*, placed on top of one another. It is necessary, in order to get the best results, to give the two pieces which are to form the loaf a further rest, after coming from the finishing moulder, and to meet this requirement a secondary or final prover is now being placed upon the market. Fig. 56 shows a longitudinal section of this machine, from which it will be seen that the dough-pieces are placed upon trays similar to those used in the first automatic prover, and moving intermittently. The loaves are given a maximum proof of 10 minutes, while the capacity of the machine is equal to the output of the full automatic plant. The loaves are removed from the prover by hand, ready to be placed on the setters.

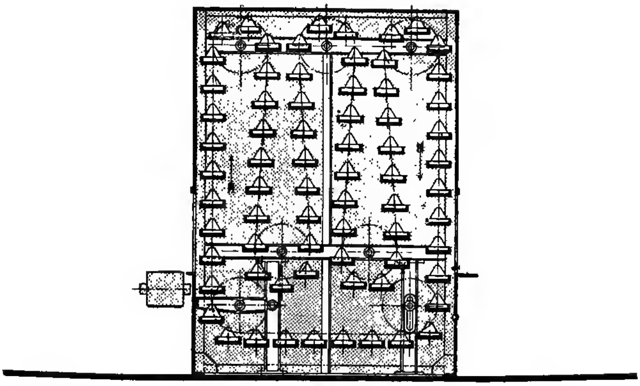


FIG. 56.—Final Prover.

597. Ovens.—This subject is still one of the most vital importance to the baker, and although the oven is obviously the oldest item in the equipment of his business, yet it has undergone greater developments during the present generation than in all the previous history of the baking trade.

If dealt with exhaustively, the subject of ovens would occupy a large volume by itself, and therefore only so much of it can be treated here, as applies to the average modern requirements and as specially affects large separate interests in this country. Among general types it is necessary to discriminate between ovens heated (1st.) internally, (2nd.) in part indirectly, and (3rd.) by purely mechanical means, *i.e.*, quite externally.

598. Internally Heated Ovens.—These may be dismissed very shortly. They consist merely of a masonry or brickwork chamber, communicating with a chimney and heated by fire direct, applied in various ways. The heat thus stored is utilised, after the oven has been swept out, for baking the bread. During all known history until modern times this was practically the only principle applied to ovens for bread-baking purposes, and it is undeniable that if the manipulation of such an oven is properly understood and attended to, perfect results as regards baking can be obtained, for at any rate the great majority of the loaves of each baking. The principal objections are want of fuel economy, loss of time in re-heating, utter dependence upon skill, and absence of hygiene.

599. Hot Air Ovens.—These are subject, more or less, to the same objections. Their construction differs from that of internally heated ovens by the furnace or fireplace being independent of the baking chamber. The heated gases from the fire are conducted through flues placed, as far as possible, in such a manner as to enable the baking chamber to be heated by the tiles, which form the covering or walls of these flues. The waste gases are, or may be, also admitted eventually to the baking chamber itself. Dampers are introduced with the object of regulating the heat, but are not invariably successful. Provided that such ovens are well designed, they bake well, and are more nearly continuous than internally fired ovens. Against this must be set the drawback that most ovens of this kind consume considerable amounts of fuel. Unless exceedingly well built, the obviously numerous flues render frequent repairs of this type of oven necessary.

600. Mechanically Heated and Electric Ovens.—These represent the modern development, and lend themselves to specialisation in astonishing variety, of which the leading examples will be reviewed after a short general survey of the "mechanical means" available for heating the ovens. This class of oven may be fairly described as externally fired, but internally heated, the significance of which characterisation will in due course become clear.

Ovens heated electrically would certainly fulfill the most exacting requirements in every respect, were it not for the fact that the electrical generation of heat absorbs far too much energy to allow of working costs which are commercially practicable. Apart from miniature ovens, for laboratory work, a few electrically heated ovens have been built, but the amount of current consumed, about 80 kilowatts per one sack batch, is so enormous that, however low a price per B.T. unit be assumed, the cost will be seen to be quite prohibitive.

Some startling revolution of the means for producing electrical current, or some equally wonderful invention for the conversion of electrical energy into heat, must therefore be awaited, before electrical heating of ovens can become a question of practical politics.

601. Perkins' Tube or Steam Pipe Ovens.—As a matter of fact, Perkins' invention of the closed circuit system, and the subsequent improvement thereon embodied in the "Perkins" sealed-end tube, was the epoch-making departure from the accepted notions of his day, which has brought about the revolution in ovens effected in recent years. It is an interesting testimony of the value of Perkins' invention that the first man to employ ovens of his make, Mr. H. W. Nevill, built up in comparatively few years an enormous business. The Perkins' invention is based upon scientifically correct principles. The boiling point of all liquids bears a definite relationship to the pressure to which the liquid is at the time subjected. The higher the pressure the higher is the temperature. The following is the principle of Perkins' apparatus:—A system of hermetically sealed pipes, completely filled with a suitable liquid, is provided, and at its highest point an expansion vessel is attached in order to accommodate the extra volume of the liquid when heated. By exposing a suitable proportion of this system of piping to the action of a fire the pressure in the apparatus was enabled to rise to the point corresponding to a temperature adequate for the baking of bread. Obviously the greater portion of this apparatus was arranged to be within the oven chamber, while the portion exposed to the fire, arranged as a coil in a brick-lined iron furnace, was placed at any convenient point, as in a stokehole or room adjoining the bakehouse. Many ovens were constructed in this manner, and remained successfully at work for many years. Perkins, however, soon concluded that it would be better to dispense with any form of joints for connecting up the various lengths of pipe, from which his apparatus was constructed. (The joint which he invented was nevertheless remarkably efficient, and is the only one used to this day for this class of work, including the "loop-tube" ovens referred to later on.) He therefore adopted the plan of using a large number of single straight tubes, welded at each end, and with a portion of each tube projecting into a furnace constructed at the back of the oven and fired from a stokehole separate from the bakehouse. These tubes were set in two rows, the lowest of which acted as firebars, and upon them the fire rested. To this day this oven is the prototype, and apart from improvements in details and adaptations to particular requirements remains unaltered. These single sealed tubes possess a practically unlimited life—they have been tested carefully after forty years of hard continuous service, and have been found absolutely intact and fit to continue their work indefinitely. They obviously avoid the risk inseparable from joints, and, unlike tubes arranged in complicated coils and intricate loopings, are readily and inexpensively replaced, should occasion arise, without interruption or disturbance of working. The so-called loop-tube ovens are a half-way stage between Perkins' earlier and later systems. The tubes, instead of being sealed at either end, are endless; that is to say, have their ends jointed up to form a continuous tube, just as is the case in Perkins' first construction. While each loop-tube is therefore much longer and more complicated in shape than Perkins' later straight tube, it is shorter than the circuit employed in Perkins' first oven. The loop-tube has nearly all the faults of the first Perkins' oven, but lacks the best points in the stopped end tube; yet experience proves that the Perkins' sealed-end tube accomplishes everything required of it by the baker, and is not excelled by the loop-tube in any single direction. Claims have been made on behalf of the loop-tube, in that ovens employing it are more economical in fuel than are ovens fitted with sealed-end pipes. This is not borne out by facts, if ovens of modern construction are compared under equal conditions; what gave a certain amount of colour to these statements is that the long narrow furnaces peculiar to earlier Perkins' construction need considerable care to ensure that the consumption of fuel be kept to a minimum. As workmen are careless, and mostly fire in the manner involving least trouble to themselves, the fuel consumed in ovens with these long narrow furnaces usually exceeded considerably the amount actually required. The "Perkins" ovens have, however, for some years been equipped with furnaces which make this impossible, and practically restrict the consumption of fuel to the amount actually required.

It follows that the sealed-end tube is considered preferable, and the reasons, in so far as they affect the baker, may be shortly stated thus: it lends itself to constructions which are as economical, as uniform in baking, and as continuous as any that are possible with any other system. In addition, it is more durable, involves less risk, avoids all possibility of an oven being put temporarily out of use, and if replacements are required, enables these to be carried out at a nominal expense. As the original patents for these various systems referred to have now expired, they are all equally available for oven manufacture.

602. Oven Types.—The withdrawable baking plate was the subject of practicable proposals by Perkins. At a later period "Wieghorst's" early productions made their appearance; following upon these the drawplate proper (Pfleiderer's patent) was actively introduced into this country towards the end of the last century, and has since spread largely over the civilised world. The drawplate proper, with plate travelling independently upon the drawplate carriage, employing only rolling bearings inside the oven, and leaving the bakehouse floor entirely unobstructed when not drawn out, has since the beginning of this century certainly become the standard bread oven for batch working. Replacing old ovens in existing bakeries, and nearly always being installed in all new bakeries with any pretence to being abreast of modern ideas, the drawplate has long ago demonstrated the fact of its entire suitability for all baking requirements. Fig. 57 shows a battery of one-deck drawplate ovens, and Fig. 58 a battery of two-deck ovens, coke fired. Fig. 59 gives a view in the stokehole of a coke-fired battery, from which the smallness of the modern furnace will be noticeable. Drawplates are made in many different sizes, to suit requirements of trade as well as to conform to restrictions in regard to space. It may be taken that the plate should not exceed 6 ft. in width in all cases where setting has to be done by hand (conf. paragraph 556), but when only bread is baked which may be handled with setters, the width may be as much as 8 ft. 4 in. Greater widths should be avoided, as leading to difficulties in setting, on account of the heavy weights to be handled.

Split Drawplates.—Fig. 60 shows a very useful modification (Pointon's patent) of the standard arrangement, enabling a drawplate oven to be adopted in bakeries possessing only a very limited floor space. The plate is cut transversely into two equal halves, and when drawn out, the special gearing shown enables the first half to be lowered, so that the back half can be drawn forward over it. After setting the batch on the back half the process is reversed. These ovens are in actual use and answer admirably; it will be seen that they not only enable a drawplate to be used where it would be otherwise impossible to do so, but that a plate,

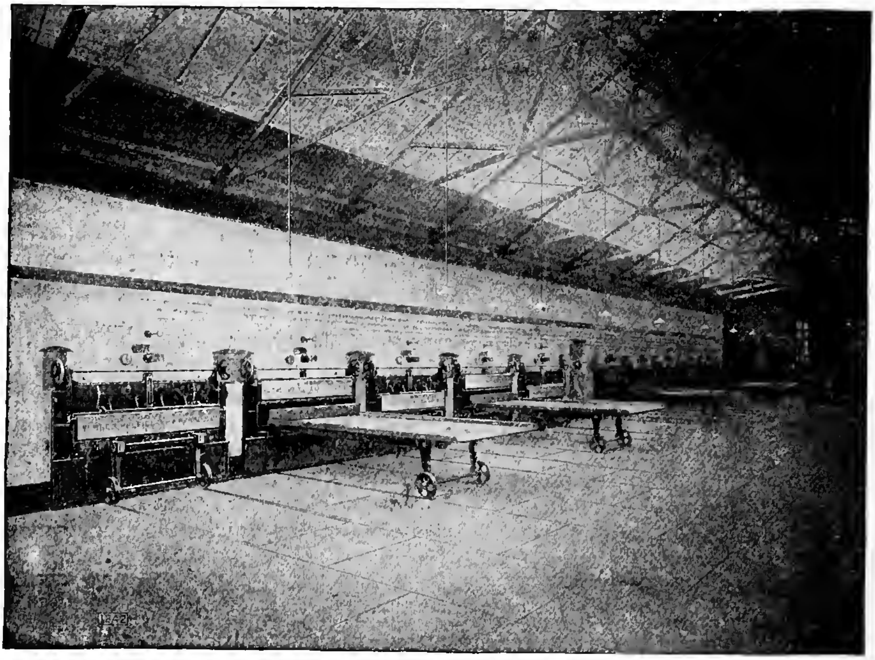


FIG. 57.—One-Deck Drawplate Ovens.

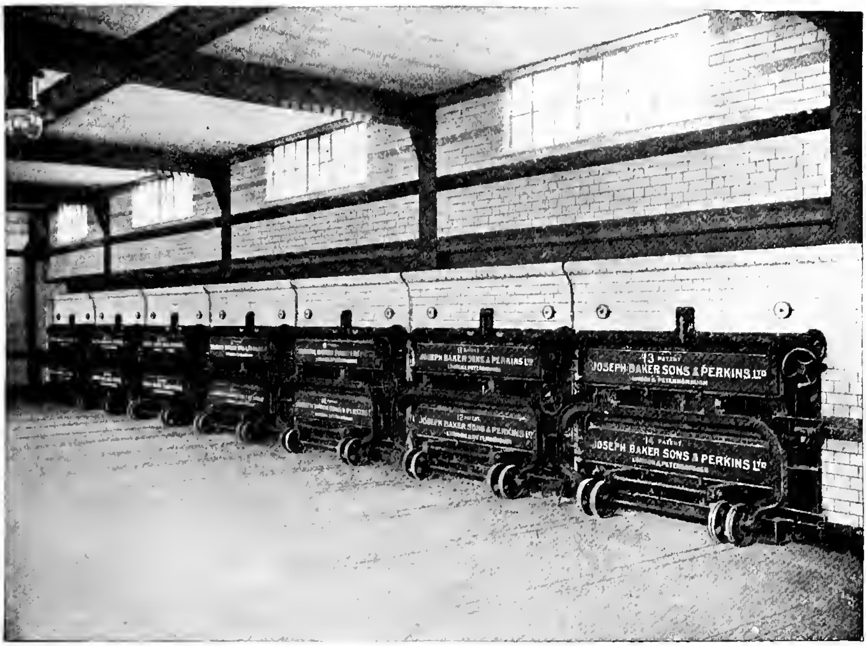


Fig. 58.—Two-Deck Drawplate Ovens.

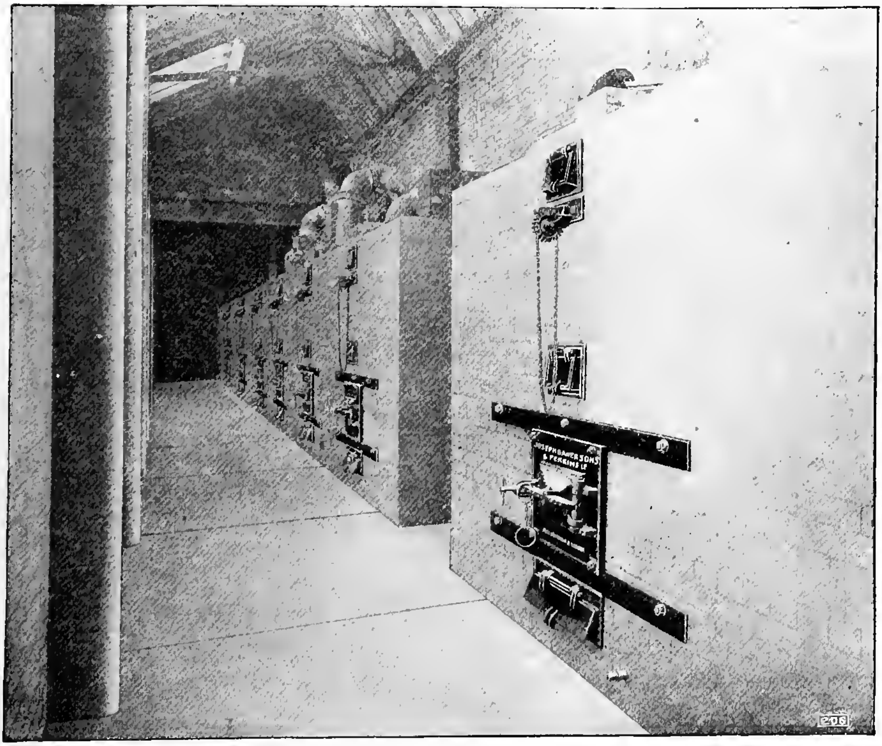


Fig. 59.—Stokehole of Coke-Fired Ovens.

about 11 ft. long, can be used in a 6 ft. space: in less space therefore than a similar size peel oven could be worked.

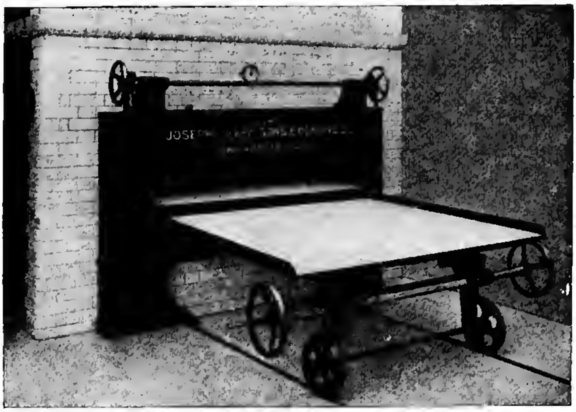


Fig. 60.—Oven with Split Drawplate.

Combined Drawplate Peel Oven.—Fig. 61 shows this very useful combination. The carriage of the drawplate carries a chequered iron plate platform (barely visible in the illustration because almost entirely hidden by the drawplate itself) from which the peel oven is conveniently worked. The step just above the car wheel gives easy access to this platform. With regard to the firing of this oven refer to "furnace arrangements" further on.

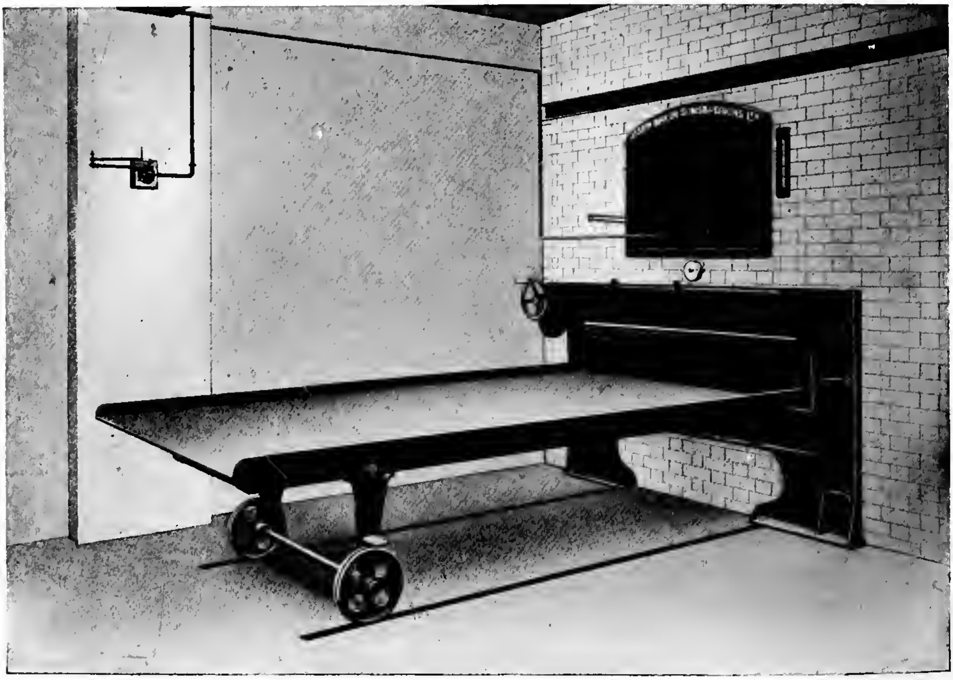


Fig. 61.—Combined Drawplate and Peel Oven.

Portable Drawplate Ovens.—A useful small oven, very suitable for caterers, is shown in Fig. 62 (Ihlee's patent). The fact that the special design of running gear employed dispenses with all outer supports, makes this oven quite self-contained and truly transportable.

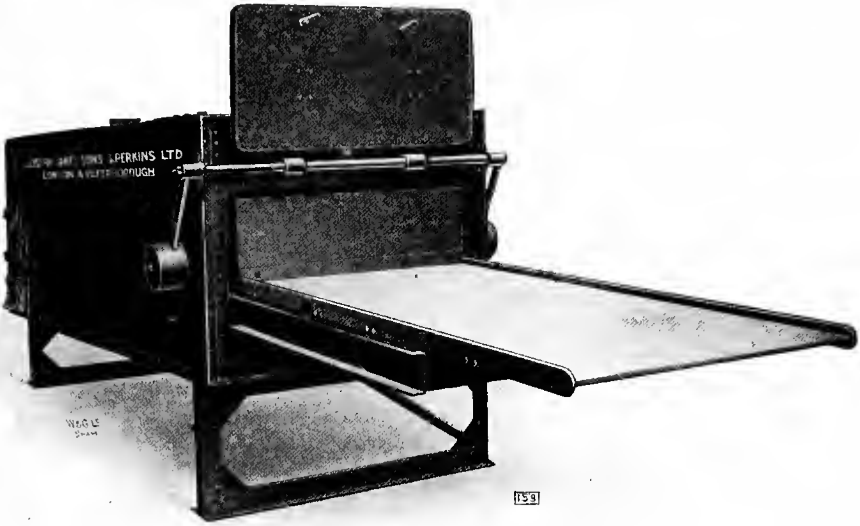


FIG. 62.—Portable Drawplate Oven.

Peel Oven.—The standard peel oven, although made in any size to suit requirements, does not call for lengthy description. Fig. 63 shows a typical arrangement of two-deck ovens with pits for working the bottom ovens.

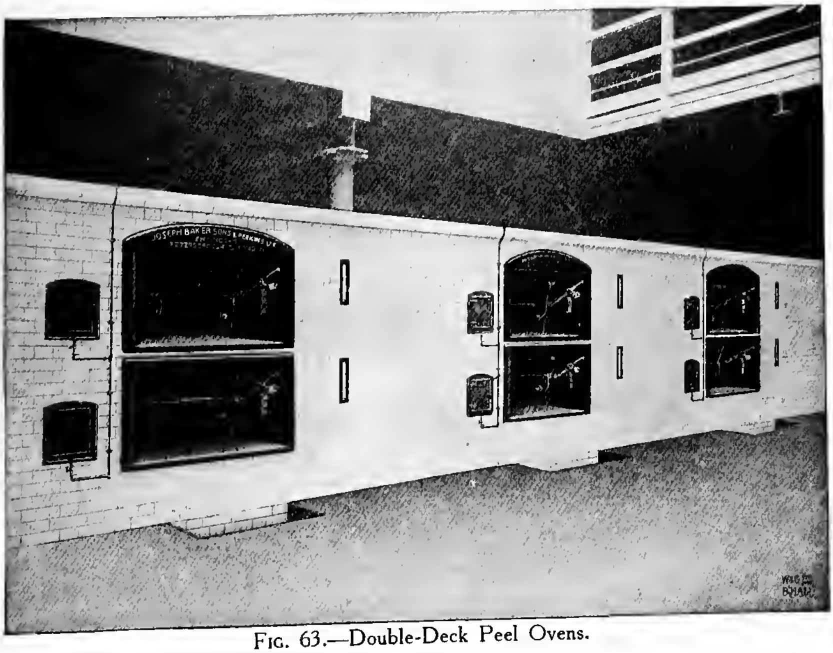


FIG. 63.—Double-Deck Peel Ovens.

Portable Ovens.—Fig 64 shows a very excellent two-deck specimen, with prover and hot-water tank.

Field Ovens, as shown in Fig. 65, are mounted on platform waggons and enable baking of the very best type to be carried on for troops in camp or on the march. This two-deck oven, although only weighing 22 cwt., bakes rations for over 2,000 men per day: a very good indication of the efficiency of the steam-pipe principle. It may be fired with coke or can be heated with wood; even green wood cut on the march answers the purpose. The insulation on these ovens, despite their elegance and lightness, is so excellent

Fig. 64.—Portable Oven.

Fig. 65.—Field Oven.

that baking has been carried on with 3 in. of unmelted snow lying on the top of the oven.

Ship Ovens.—War ships and merchantmen are now as well equipped as any establishment ashore, and carry fully equipped bakeries with kneading machines, mostly driven by electric motor direct, and steam-pipe ovens. Fig. 66 shows one of the large size and substantial two-deck ovens carried by our large liners.

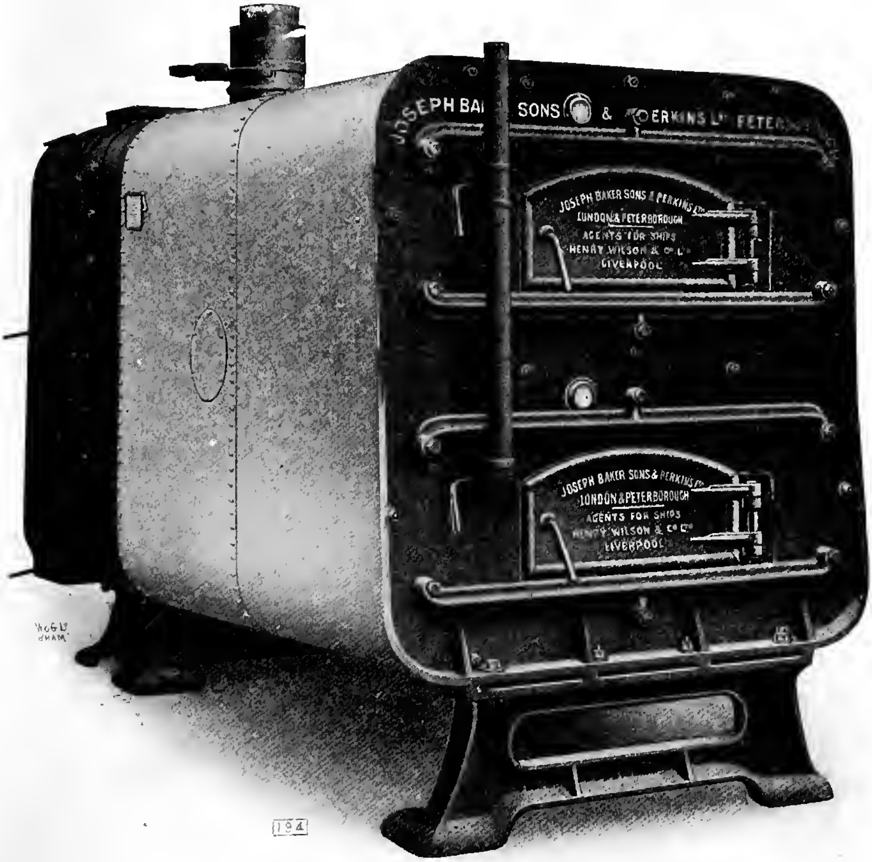


Fig. 66.—Ship Oven.

Hotel Ovens.—Large hotels and businesses with dining accommodation for large staffs frequently provide themselves with modern equipment, and Fig. 67 shows a typical case of this kind. In this the oven seen on the left-hand side is a "Vienna" oven with sloping sole, powerful steam generating apparatus, steam valve for drawing off vapour, and patent oven-light to protect the gas jet from the effects of steam. This type of oven is fitted with the Monier sole, referred to in a subsequent paragraph, and admirably bakes rolls of the true Vienna style—that is to say, rolls with a thin "egg-shell" crust and perfect bloom and gloss for consumption within a few hours of baking. Vienna rolls, as more often required in this country, require an oven somewhat differently arranged, and are better produced by the aid of steam from a boiler as they must be soaked more thoroughly and require a heavier crust so as to keep brittle for a longer period.

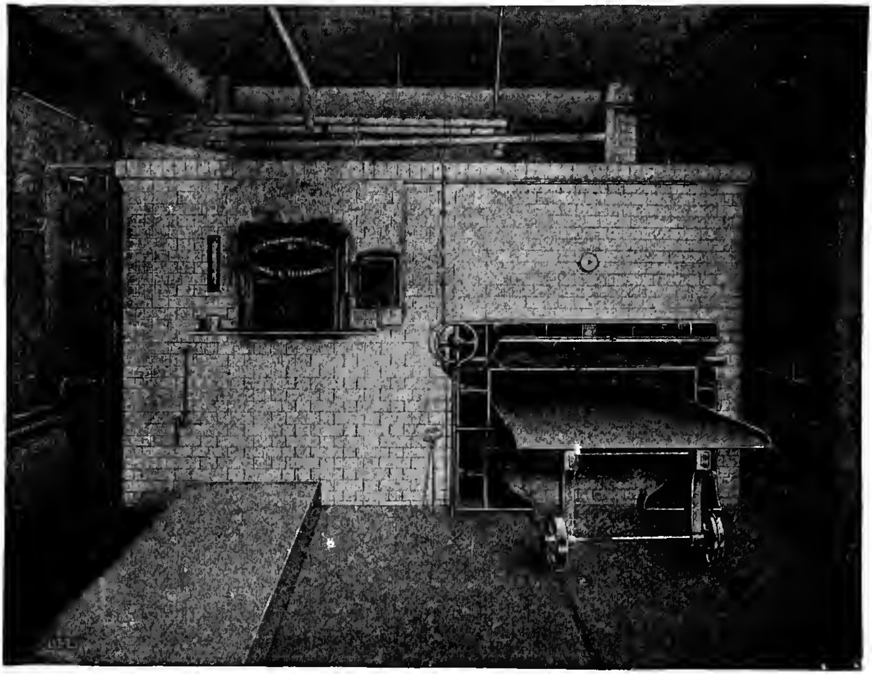


Fig. 67.—Hotel Oven.

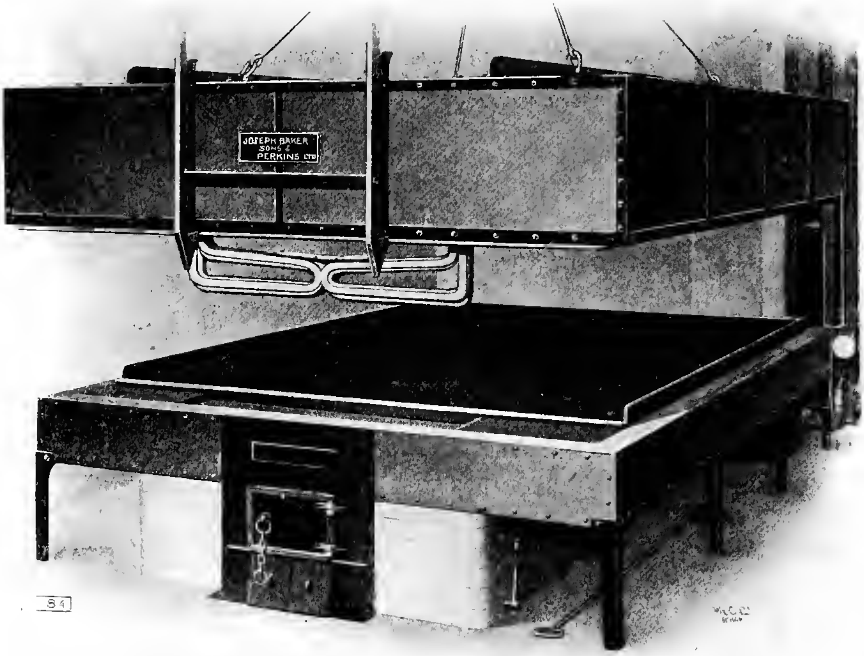


Fig. 68.—Coverplate Oven with Cover Lifted.

Coverplate Oven.—A very special type of oven has been quite lately produced, which cannot be classified either as a peel or drawplate, and to which the name of "Coverplate" oven (Ihlee's patent) has been given. It is essentially a hot plate, fitted with a removable lid or cover, in which is arranged a system of pipes to give top heat. The idea is to give a large batch capacity (40 dozen 2 lb. loaves) in a minimum of working space, with the least possible weight and expense. The oven is designed to deal with Scotch batch bread, but might also suit similar classes of goods much made in Ireland. The furnace gases can be taken over the tops of the loaves to give the "flashing" effect required in Scotland. Fig. 68 shows the oven as fitted in a Glasgow bakery, where the work done appears to be excellent and to meet the high standard demanded there. When the cover is lifted, as shown in Fig. 68, the method of procedure is of course exactly the same for setting and drawing a batch as would be the case with a drawplate. For the many existing bakeries in Scotland, with flats on upper floors, the scheme, if practicable, would appear to possess marked advantages because of the great saving in weight, combined with economy in floor space.

Arrangement of Furnaces.—All the ovens referred to can be built to be fired from the front, back, or at either side, but of course preference must be given to back firing in all cases where exigencies of space do not make this impossible. One furnace to two baking chambers, as in two deck ovens, should be avoided because, notwithstanding any claims to the contrary, effective control of each chamber is only possible when each chamber has its own furnace. The drawback to having a furnace to each, in two-deck ovens, has hitherto been that this construction entailed having the sole of the upper oven at an inconveniently great distance from that of the lower one. Beanes' patent construction avoids this difficulty, and enables the soles to be kept at the same minimum distance apart as in the two-deck oven with one furnace. For the purpose of these observations it is assumed that each chamber has at least two rows of tubes, as in some cases ovens are built with two decks and only three rows altogether. This is bad practice, and does not lead to a saving at all commensurate with the loss in efficiency, durability, and continuity of the oven.

603. Oven Fittings.—Drawplate ovens are commonly equipped with a "dummy" clock to each chamber for marking up the time at which the batch should be drawn. There is also a mercurial thermometer and means for injecting steam, while efficient steam generators may be arranged for if required. Peel ovens are fitted with a thermometer, and either a gas bracket or patent oven-light as may be desired. The latter has the advantage of lighting up the oven without being affected by the steam; oil lamps are supplied where gas or electricity is not available. Doors, arranged to slide vertically, should be fitted for Vienna ovens, or where small goods require setting in a bath of steam, as the doors may then be readily adjusted to a convenient height, while retaining the steam at a lower level than would otherwise be the case.

Pyrometers are quite out of date in steam-pipe ovens, as the temperature can never rise to a point which would endanger a thermometer, which is, if of good make, absolutely reliable and will always read accurately. Good working instructions should be insisted upon with new ovens, and kept in a conspicuous place in the stokehole. Their observance should be rigidly insisted upon by the proprietor or manager.

As regards oven soles, all ordinary styles of bread current in this country will be baked satisfactorily on iron soles. A very useful method of indelibly marking each loaf with the name or trade-mark of its maker is possible with drawplates, by having the plate divided into suitable squares, in each of which the desired mark is cast, so that it is positively baked into the loaf. The plan is in use in many places and answers admirably. For Vienna rolls, etc., a sole of earthenware material is often preferred. "Monier" soles, as manufactured by Perkins, have proved entirely satisfactory in these cases, and can be strongly recommended as having now stood the test of over fifteen years' continuous working. Tiles must be condemned, as they tend to interpose too great a resistance to the transmission of heat from the tubes, the safety of which is thereby endangered.

The cases where iron soles do not fully over all requirements are, however, comparatively few and far between.

604. Automatic Travelling Ovens.—Travelling ovens of the type used in biscuit manufacture are not directly suitable for bread-making. For the production of modern thin-crusted loaves with a rich bloom, adequate bulk and for baking with a minimum loss of weight in the loaf, special constructions ensuring the retention of an atmosphere suitably charged with steam are essential. Of types specially adapted for the production of high class bread there are now quite a number of travelling ovens working successfully in Great Britain and elsewhere, both on the single tunnel plan and with chains operating on a circuitous route conveying the loaves on swinging trays in combination with direct heating internally by coke or high pressure gas and by Perkins' tubes. Some of the swinging tray ovens have their chains integral with those of the final provers and are therefore automatically charged, as are others which have provers operated by separate sets of chains. This subject is, however, so complicated by technicalities and dependent upon conditions in individual bakeries, that no detailed descriptions can be included here.

605. Oven Firing.—It is not possible to give any detailed instructions on this subject, as the treatment must necessarily vary considerably for different makes of ovens. It may, however, be said that where possible in regard to cost, coke is much the cleanest and most satisfactory fuel to use. It saves much trouble and dirt and avoids all risk of creating a nuisance by the emission of smoke. With every kind of fire, and especially with ovens, "little and often" should be the golden rule in adding fuel. The saving of trouble by filling furnaces to their fullest capacity, and often beyond that, is pernicious: it literally wastes an enormous percentage of the fuel and leads to exceedingly bad results in the bargain. Avoid burning rubbish, an oven furnace is not a destructor, and avoid offal—egg shells, remains of meat, etc., especially if an oven be fitted with a copper boiler, as gases are formed which are detrimental to the copper. Do not use coke in large unbroken lumps—pieces about the size of a duck's egg are quite the maximum that should be allowed. Keep the flues clean by regular periodical sweeping, and remember that the tube ends should also be kept clear of dust. For the rest it is necessary to follow the directions supplied by the oven builders.

606. Nature of Coke Combustion.—This subject is of great practical importance in connection with the whole question of the firing of oven furnaces, and so merits a somewhat careful examination. First of all, coke has the advantage of producing an absolutely smokeless fire, and so soot deposits and their inconveniences are practically obviated. On the other hand, the flameless combustion of carbon produces heat which is not only intense but also very local, so that the furnace itself is very hot, in comparison with flues at some little distance. This necessitates careful designing, so that due provision shall be made for the ready transmission of this local heat; granted proper arrangements, however, this localisation of heat in no way interferes with the perfectly efficient working of coke-fired ovens, it in fact constitutes an advantage.

Although coke itself burns flamelessly, yet one usually sees more or less pale blue flame over the surface of a coke fire. This is due to a process similar to that which is utilised in a producer and arises from the formation and subsequent combustion of carbon monoxide, according to the following equations. The air, in passing up through the red-hot coke of the fire, forms carbon monoxide thus:—

$$\underset{\text{Carbon.}}{2C} \quad + \quad \underset{\text{Oxygen.}}{O_2} \quad = \quad \underset{\text{Carbon Monoxide.}}{2CO.}$$

The gas rises to the surface, and there, on meeting with excess of air, undergoes combustion, thus:—

$$\underset{\text{Carbon Monoxide.}}{2CO} \quad + \quad \underset{\text{Oxygen.}}{O_2} \quad = \quad \underset{\text{Carbon Dioxide.}}{2CO_2.}$$

In this way the production of carbon monoxide indirectly causes a flame combustion from coke, and thus produces heat in such a form as to be more readily conveyed away, so far as the flames will reach, from the furnace into the flues. But unless complete combustion of the carbon monoxide occurs, there is a very serious loss of heat. This is readily seen by studying the thermal effect of the burning of carbon and carbon monoxide respectively. One gram of the former evolves during combustion 8,080 heat units, while the same quantity of the latter produces 2,634 heat units. From the equations above given it is readily calculated that 1 gram of carbon produces 2.33 grams of carbon monoxide. And further, this quantity of carbon monoxide must produce in burning

$$2.33 \times 2{,}634 = 6{,}146 \text{ heat units.}$$

But as the gram of carbon only evolves 8,080 heat units, we have 8,080 — 6,146 = 1,934 heat units produced in the burning of 1 gram of carbon to monoxide.

Summing up:—

	Heat Units.
Heat produced by 1 gram of carbon burning to monoxide	1,934
Heat produced by the combustion of the carbon monoxide yielded by 1 gram of carbon	6,146
Total	8,080

Whatever quantity of carbon monoxide, therefore, that escapes combustion, means a loss of over three-quarters of the heat-producing power of the carbon it contains. To prevent this loss, air should gain access to the coke gases after they leave the coke. In practice this end is sometimes attained by letting the furnace doors be slightly open—it is possible, however, by having the opening too large, not only to cut off the draught from the fire, but also to absolutely cool the oven by the admission of excess of cold air into the flues. Theoretically, the right thing might appear to be to keep the furnace closely shut, and thus favour the production of carbon monoxide, providing for its combustion, beyond the fire, by admitting air on the flue side of the "bridge" or back wall of the furnace. Such an opening would need to be regulated so as to admit the exact quantity of air with the utmost nicety, as too little would mean imperfect combustion, and too much a direct cooling of the oven. In practice there would be considerable difficulty in carrying out this idea.

607. Water Heating.—The problem of heating water for a bakery requires more careful consideration than it usually receives. The widely current notion that nothing could be simpler or better than a boiler over the oven furnace is perhaps not unnatural; especially bearing in mind that such an arrangement ensures a good supply of warm water directly on commencing work after a period of rest. As a matter of fact, however, there are serious objections to this plan, and an independent apparatus must be recommended as preferable. In the first place, it is wrong to suppose that there is any saving in fuel by having a boiler over the furnace; assuming of course that in comparing such an arrangement with an independent heater both are properly constructed. Nature never gives anything for nothing, and water cannot be heated in an oven boiler without a corresponding amount of fuel. There are of course ovens which part with their waste products of combustion at so high a temperature that they can be utilised for heating water in adequate quantities; but these can not be here considered as we are dealing with modern ovens, which, if properly constructed, do not waste heat to this extent. In the second place, it must always be remembered that a boiler constitutes a local demand for heat, at such times especially when much hot water is drawn off, and this necessarily tends to rob the oven of heat in an uneven manner, besides checking the temperature generally at times which bear no relation whatever to the legitimate functions of an oven. Further, a boiler buried in brickwork is much subject to deterioration, while being at the same time inaccessible to inspection; the result is therefore usually that the time comes when it gives out without warning, drowns the fire and spoils the bread by interfering with the baking, to say nothing of the inconvenience caused and the probable disturbance of work while repairs and renewals are effected.

Fig. 69.—Water Heater.

Excellent independent heaters are now available, and a very good type is illustrated in Fig. 69 (Perkins' patent). The boiler proper, consisting of a cylindrical vessel, with a domed lid which is removable, will be seen to be mounted upon a cylindrical furnace. Perkins' tubes, arranged in a circle, pierce the bottom or tube plate of the boiler, and convey the heat from the fire, which lies within the basket of pipes formed by the tubes, to the water above. The fire therefore lies on a small circular fire-grate, and is walled in on all sides by the vertical tubes. Thus no firebrick lining is necessary, and renewals are confined to the fire-grate, a very small affair; whereas the boiler top can be readily lifted for the removal of scale. This scale can only form on the tubes as these constitute the only heating surface for the water, and owing to the fact that expansion and contraction of the tubes takes place, the brittle scale automatically chips off as soon as it has accumulated to any appreciable thickness and collects at the bottom of the boiler ready for removal.

The boiler must always be kept full of water, and this is readily assured by a supply being provided by means of a ball-cock supply tank (as shown in illustration) under a sufficient head to drive the water to the highest point at which it is desired to draw off.

Before leaving this subject it is necessary to point out the importance of always selecting materials suitable to the nature of the local water supply. Hard waters are usually neutral to galvanised surfaces, and in all such cases therefore galvanised pipes and boilers meet all practical requirements. Naturally, hard waters deposit the greatest amount of scale, and the apparatus described above is then the best, as no trouble will ensue so long as the scale deposited at the bottom of the boiler is periodically cleaned out. Soft waters, especially moor waters derived from areas with large deposits of peat, corrode iron and steel very rapidly, especially when hot; and galvanising also proves no protection in such cases. To meet these conditions, the independent heaters are supplied in copper, as regards all surfaces which come in contact with the water, or, to avoid undue expense, with copper-coated surfaces. As entire destruction through pitting and corrosion may take place in so short a time as 12 or 15 months where galvanised iron or steel are used, the importance of this point will be appreciated.

608. Complete Automatic Bread Bakeries.—Before leaving the subject of bakery equipment it may be of interest shortly to refer to bakeries which dispense entirely with skilled labour; excepting always, of course, the need for good judgment and expert knowledge required in making dough by the aid of the machines and regulating properly its subsequent growth and development. Such bakeries are entirely within the range of practical politics for the production of uniform loaves which are within the scope of the machinery employed and have in fact to some extent already come into everyday use and can be multiplied indefinitely where the output required is sufficiently large (say 500 sacks per week and upwards). Assuming a trade of 500 sacks per week consisting of nothing but 2 lb. tin bread (or of the cottage or coburg varieties), eight men would be sufficient to take the flour from the flour store and deliver the finished bread on to trucks in the bread-room, and of these only three men would need to be bakers. It will be clear that the cost of production is thus brought down to a minimum, and as the baked bread is discharged into the bread-room by the automatic oven, transportation throughout the whole process is carried out by mechanical means.

609. Scotch "Chaffing" or Moulding Machine.—Another special adaptation to local requirements is represented by a machine for performing the final operations required in "Scotch" batch bread (Pointon's patent). In the manufacture of Scotch bread, although the dough-making process follows entirely different lines to those generally adopted in England, the machines used, as far as dividing, handing-up, and proving are concerned, are exactly similar to those described in paragraph 587 *et seq.* But the final operation of moulding the loaf is on an entirely different principle to that of the balling-up type so far referred to. Instead of working the dough-piece up into a ball shape as described in paragraph 587, the Scotch practice demands that the piece be pressed out into a flat sheet, stretched, folded over, pressed again, and finally folded into an oblong packet ready to be placed on the setter. These operations are very difficult to accomplish mechanically, especially as they are of a non-consecutive nature, but would appear to be perfectly accomplished by Pointon's Patent Chaffing Machine.

610. Bakery Registers.—An almost integral part of the economy of a machine bakery, and in fact any bakery of modern pretensions, is a register of particulars of the making of each batch of the day's work. This should be in book form, and affords, when properly kept, a most valuable record of work done, and also gives the means of checking same from day to day. The authors have had printed a register in which the following is the heading of the day's work:—

BAKEHOUSE REGISTER.			TEMPERATURE.	
			Day.	**Night.**
.........................19....	Highest	....	....	....
	Lowest	....	....	....

Temperature of bakehouse at time of setting 1st sponge or dough.......

There then follow the various column headings, arranged right across two pages of the book, in the following order:—Number and kind. Water (quantity). Temperature. Yeast, kind and quantity. Salt. Flour. Flour temperature. Sponge when set. Temperature when set. When taken. Remarks. Time when taken. Water. Temperature. Salt. Flour. Dough temperature. Oventime. No. of Loaves. Remarks.

Such a register may be amplified, simplified, or modified, according to the requirements of any particular mode of working. The system of testing the temperature of a sponge when set, and when taken, often gives useful information as to its condition. With any uniform method of working, the amount of rise in temperature is very nearly a constant quantity. When the rise is excessively low, the sponge is likely to have been starved or the yeast to have been weak. If, on the other hand, there is an abnormally high rise, the fermentation will have been too vigorous, and have proceeded beyond its proper limit. In either case a useful diagnosis of the condition of the sponge is afforded at a time when it is possible to take steps toward remedying either evil. Subject to certain limitations, the same remarks apply to straight doughs.

CHAPTER XX.

ANALYTIC APPARATUS.

611. Commercial Testing and Chemical Analysis of Wheats and Flours.—As a matter of convenience, the various analytic operations involved in the testing and examination of wheats and flours are divided into two classes: first, those which are more readily performed, and which afford information having the most immediate bearing on the actual value of these bodies; and second, those determinations which are more purely chemical in their nature. The operations of the first class are comprised under the heading of "Commercial Testing of Wheats and Flours"; their nature is such that they may be performed personally either by the miller or baker. The second series of tests requires rather more chemical knowledge and experience: they consequently appeal more particularly to the students of milling and baking who have had the advantage of a course of chemical training in a properly appointed laboratory.

A description of the laboratory, and of the principal analytic apparatus used in weighing and measuring, will now be given as an introduction to analysis.

612. The Laboratory.—For the benefit of any millers and bakers who may wish to fit up a laboratory for themselves, the following few hints as to utilising a room for the purpose are here inserted. If any work is to be done beyond the roughest experiments, a balance and microscope will be requisite; these delicate instruments must be kept free from dust, and so cannot be exposed to the ordinary atmosphere of the mill; they should therefore be placed in either a private office or study, and covered over when not in use. For the other purposes of a chemical laboratory, almost any room, or part of a room, can be made to answer. A working bench or table should be fitted in as good a light as possible, at a convenient height. Gas, when obtainable, should be laid on to this bench by means of a pipe terminating in a nozzle, over which a piece of india-rubber tubing can be slipped. There should be near at hand a drain, over which is fixed a tap, with a good water supply. This tap should also have a small side tap, with nozzle for india-rubber tubing, in order to lead water into any apparatus in which it is required. These are almost the whole of the necessary fixings. There must of course be a few shelves on which bottles and the various apparatus may be kept. With time and money to spare, many additional fittings might be suggested. These can, if wished, be added afterward.

613. The Analytical Balance.—It is presumed that the student before attempting the following work, will have made himself familiar with the simpler chemical apparatus by their actual use in the laboratory. Quantitative analysis, as its name implies, is that species of analysis by means of which the quantity or amount of each ingredient in any particular body is determined. For purposes of analysis, quantity is measured and expressed either by weight or by volume. Accordingly, the chemist first of all requires some accurate means of determining with exactness both weight and volume.

For purposes of weighing, an accurate balance and set of weights are necessary. Of these there should be in a laboratory at least three of different degrees of sensibility. Taking the most delicate first, let us describe what may be termed the "analytic balance proper." This instrument requires to be made with the utmost care and accuracy, and is illustrated in Fig. 70. The specialty of this particular variety is that the beam is very short; it is claimed for it that, as a result, the delicacy of the balance is increased, while the time in which a weighing is performed is lessened. On referring to the figure it will be noticed that the balance is enclosed in a case; the bottom of this consists of a stout slab of glass, fixed on levelling screws. The front, back, and sides of the case are glazed; and all open, the front and back by sliding up, the two sides on hinges, as doors. The beam is suspended on a pillar, which in turn is screwed down to the bottom of the case. The beam carries at its centre a knife-edge made of agate; this rests on a plane of the same material; on each end of the beam there are similar knife-edges, and from these

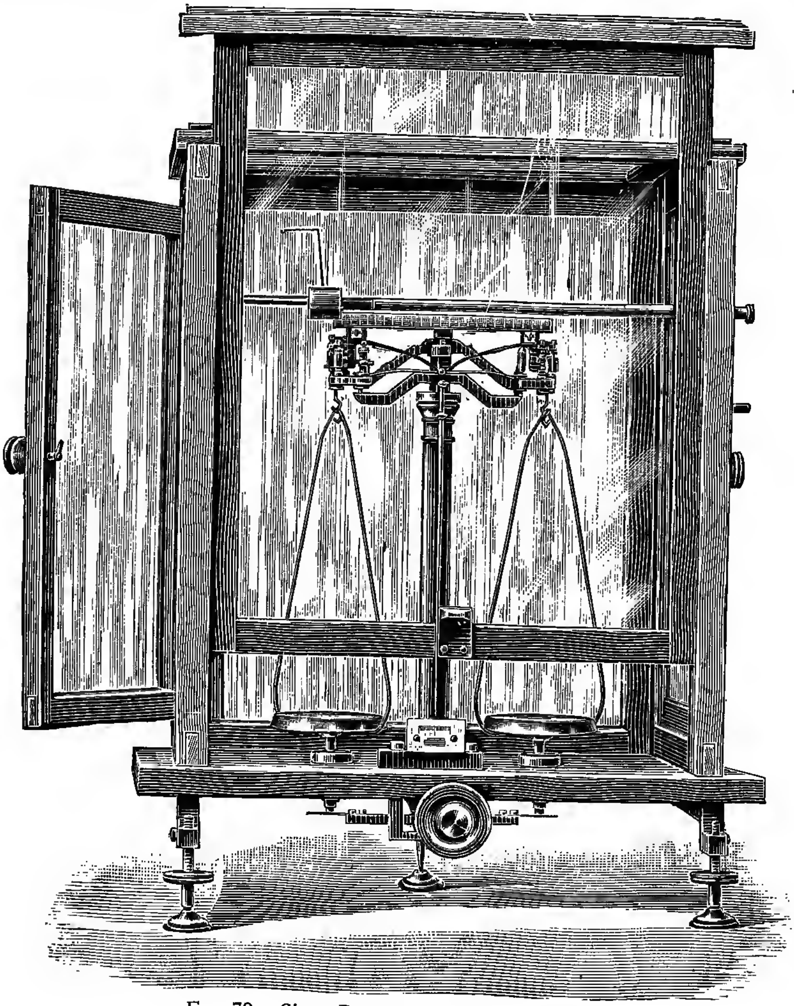


FIG. 70.—Short Beamed Analytical Balance.

depend the scale pans. When the balance is not in use, the beam, instead of bearing its weight on the knife-edge, rests on a sort of cradle; so, too, the end hooks carrying the pans are likewise supported by the cradle. Underneath each pan there is also a small support on which the pan rests until it is required to set the balance in action. In the centre of the front of the balance, and immediately underneath the glass base, is fixed a large brass milled head; this, on being slowly turned by the operator, first lowers the supports from beneath the pans, then drops one portion of the cradle, and so suspends each scale pan from the terminal knife-edges of the beam, and next lowers the central knife-edge on to its agate plane, and permits the balance to swing. On turning the milled head back again, the opposite of these movements takes place in reverse order, and each knife-edge is gently lifted from the agate plane. The object of this is to prevent wear of the edges by their being continually in contact, particularly as a balance would soon be seriously injured by the jarring caused to knife-edges and planes by putting on and removing weights while these were in contact. It must be borne in mind, as a golden rule of weighing, that **nothing must be added to or removed from either pan of the balance when the instrument is in motion.** In order to show the movement of the beam, there is a long index finger descending from its centre and moving in front of an ivory scale at the bottom of the pillar. A description of the mechanism employed to effect these various movements is unnecessary, as they can readily be understood by a few minutes' careful inspection of the instrument itself. Some other attachments of the balance will be better understood when we come to describe the operation of weighing. It a student is working in a laboratory under the direction of a teacher, he will find balances there, and already properly adjusted; in case that he happens to have purchased one for his private use, all the adjustments will have been made by the maker, and should not be interfered with by him unless he is thoroughly acquainted with the mechanism of a balance. It should always be borne in mind that a balance must on no account be altered or re-adjusted except by some responsible person; there may be several persons working with the balance, and the one, by altering it, and possibly setting it wrong, may upset the work of all the others. Suppose a student has procured a balance for his own private use, let him place it in its permanent position, which should be on a stout bench or table in a dry room, and at a height convenient for weighing when sitting down. The light should, if possible, be from a window behind the balance; that is, the balance should be so placed that the operator is facing the light, which should not be glaring, while it should be good. Occasionally, in a balance so placed, the ivory scale at the base of the pillar is in such deep shadow as to be scarcely readable. This may be remedied by folding a piece of white cardboard at right angles and placing it in front of the scale. It will be below the range of the eye, and acting as a reflector will sufficiently illuminate the scale. A light coming from a high window behind the operator also answers, but a strong light from either side is not suitable for weighing. The first thing to do is to get the pillar of the balance vertical. In the balance, a plummet hangs from the back of the pillar, immediately over a corresponding index point on the base; the two levelling screws in front of the balance must be turned in one direction or the other until the plummet is directly over the index point; the base of the balance will then be horizontal. In the next place carefully dust the beam and the pans with a camel's hair brush. Then turn the milled head which actuates the balance, and allow the beam to vibrate; it will most likely swing one way or the other immediately the beam is liberated, but if not, open the right-hand side door and waft a *very gentle* current of air down on the one pan with the hand. Close the door again, and watch the vibrations of the index finger; it should be explained that all the sides of the case must be kept closed as much as possible during the operation of weighing. The little ivory scale has its zero in the centre, the divisions count each way from it, and are usually ten in number on each side. Should the balance be correctly adjusted, the index finger will swing the same number of degrees each side of the zero, and after a time, as each vibration becomes shorter, will come to rest over the middle of the scale. Strictly speaking, the distance travelled on each side must be slightly less than that of the other: thus, supposing the index travelled to 9 on the left hand, it would, when the balance is correct, swing slightly less than 9 to the right, say 8.9, and then back to 8.8 on the left. With a good balance this diminution is so little for one or two vibrations that practically we may say that it should swing equally on both sides.

Such a balance as that described is capable of weighing to the tenth of a milligram, with a weight of two hundred grams in the pan. In addition to this instrument a coarser balance is also necessary; this should be capable of carrying a kilogram, and weighing to the hundredth of a gram.

614. Adjustment of Balance.—In case when testing the balance the index does not swing to the same distance on either side of the zero of the scale, first of all again dust the balance most carefully, and test once more. In the event of this not removing the error, the beam must be readjusted; there will be seen two little balls, one on either side of the top of the beam, and running on two slender horizontal screws attached to the beam—on the side which is the lighter, screw the ball very slightly from the centre of the beam, and again test. Repeat this until the two sides of the beam exactly counterpoise each other. When once adjusted, a balance, if kept clean, needs no alteration for a considerable time, provided always that it be carefully and delicately handled. In different makes of balance the modes of adjustment vary; the maker will, however, in every case either give directions or see to the proper adjustment of the instrument before it leaves his hands in case of its being a new one. For a very clearly written and most interesting chapter on the mechanical principles and management of the balance, the student is referred to Thorpe's *Quantitative Analysis,* published by Longmans & Co.

615. Analytic Weights.—After the balance, the next thing required by the chemical student is an accurate set of weights. As a rule the chemist returns his results in percentages; it is not therefore of very great importance to him, from that point of view, what unit of weight he adopts. In England, chemists either use grain weights or else those of the French metric system. When grain weights are employed, the set contains pieces varying from the hundredth of a grain to 1,000 grains. From its much greater simplicity, weights of the metric system are now used to a much greater extent than grain weights. Not only is there this advantage of greater simplicity, but, in addition, they have become the international system for scientific purposes; for this reason, as well, it is highly advisable that all chemists and students of chemistry should learn to work with these weights. Whatever weights are employed a few very simple factors suffice to convert those of the one denomination into those of the other. In Chapter I. is given a table of the most important metric weights and measures, together with their English equivalents.

The set of weights employed for analytical purposes must be of the greatest possible accuracy. They usually range from 50 grams to a milligram. The heavier weights are made of brass and then electro-gilded; the fractions of a gram are made of stout platinum foil. In shape, the brass weights are made slightly conical, and are each fitted with a small handle at the top, by which they must be lifted; for the same purpose each of the platinum weights has the top right-hand corner bent at right angles to the weight. These weights are arranged in a box, each being placed in a separate compartment, those for the gram weights being lined with velvet; the smaller weights are further protected by an accurately fitting cover of glass. For the purpose of lifting the weights a pair of forceps is provided; this has its place in the box. **Analytic weights must on no account be touched with the fingers.** Most sets of analytic weights contain the following pieces arranged in the box in the order shown below:—

50	20	10	10	5	
	1	1	1	2	
0.5	0.2	0.1	0.1	0.05	
0.001 0.001 0.001	0.005	0.01	0.01	0.02	Rider.

The student will require to learn, not only the denomination of each weight, but also its place in the box. He must be quite as well able to read the weights he has placed in the balance pan from the empty spaces as from the weights themselves. As soon as the weights are done with they should always be returned to the box; this should be further protected by being kept in a case made for it of wash-leather. The accuracy of all analysis depends on that of the weights; too great care cannot, therefore, be taken to preserve them from injury.

In giving the denominations of the weights above there is a place marked "Rider"; the nature and use of this particular weight remains to be explained.

The arrangement of the weights, as shown in Fig. 71, corresponds with the table just given of their value. Special attention must be directed to the "Rider," which is drawn to its full size at A.

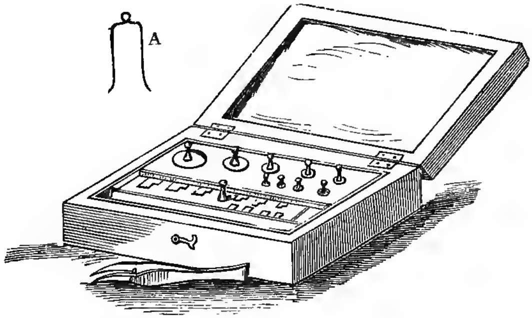


Fig. 71.—Box of Analytic Weights.

The student must now refer again for a moment to the figure of the balance previously given; he will there notice, at the top right-hand corner, a milled head; this actuates a rod, at the other end of which, from a little hook, depends the rider, as shown just over the left-hand pan. From end to end of the beam itself there also runs a graduated scale; this scale is divided into twenty equal parts, the centre is marked zero, and the other graduations numbered 1-10 from the centre towards each end. Each of these units is still further subdivided into 5 or 10 equal parts. This scale is the exact length of the beam, measured from one to the other of the terminal knife-edges. An inspection of the balance itself shows immediately that, by means of the milled head and rod attached thereto, the rider can be placed astride the scale at any part of its length. The weight of the rider is one centigram, consequently, if placed in the pan of the balance, or at 10, the extremity of the scale, the effective weight of the rider is the same as its absolute weight. But if it be placed somewhere intermediate between the centre and end of the beam, its effective weight is between 0 and 1 centigram. The effective weight is governed by the well-known principle of the lever, namely, that the force exerted by any weight is directly proportional to its distance from the fulcrum. As each side of the beam is divided into 10 equal parts, the weight of the rider at each division is the number of tenths it is from the centre: thus, at 5, its weight is equal to 5/10 of a centigram, or 5 milligrams, and so for each graduation and intermediate fraction.. The employment of the rider in actual weighing will be gathered from the next paragraph.

616. Operation of Weighing.—In performing this operation, let it be supposed that the student has balance and weights in readiness, and requires to obtain the weight of some particular piece of apparatus; this, whatever it is, must be thoroughly cleaned and dried, and then placed on the left-hand pan of the balance. For this purpose the front of the case of the balance may be raised, or if working with a balance with side-doors, that on the left hand may be opened. **Two rules of weighing are: 1st, always place substance in left-hand pan, and weights in the right; 2nd, keep the doors of the balance case closed whenever possible.** Let the weight of the piece of apparatus in question, say a crucible, be 17.8954 grams; by the following method this figure will have been ascertained. First take the 20 gram weight from the box by means of the forceps, and place it in the right-hand pan, release the beam from its support by turning the milled head: notice whether the left or right-hand pan of the balance is the heavier. In this case the weight will be too much, and the index finger will swing to the left. Bring the balance to rest by turning the milled head, and take out the 20 gram weight, and replace it by the 10 gram, try whether sufficient—not enough, add 5 grams—still too little, add 2—too little, add 1—too much. Do not forget that every time before a weight is added or removed the beam must be brought to rest on its supports; this is always to be done gently and carefully. After the addition of each weight the beam will have swung over more slowly; with the 18 grams in the pan the swing of the index to the left will have been much slower than any preceding it, showing that the actual weight of the crucible is being closely approached. Return the 1 gram weight to its place in the box, and next try 0.5 gram—not enough, add 0.2—not enough, add 0.1—not enough, add 0.1—too much. Replace the 0.1 and try 0.05—not enough, add 0.02—not enough, add 0.01—not enough, add 0.01—not enough. The weight has now been ascertained within a centigram, because the addition of another centigram would bring the weight up to the 0.1 gram, which has already been tried and found too much. The conclusion of the weighing should now be done with the rider. Place the rider on the 5 on the right-hand end of the beam, lower the supports, cause the beam to vibrate, and shut the door of the case. If necessary, waft with the hand a gentle current of air on to one of the pans in order to set the beam in motion. Count the number of graduations which the index moves on either side of the zero; it will be found to vibrate slightly more to the right than to the left. Next try the rider on the 6th division; this is found too much. Try the rider at intermediate distances until it is found that the beam swings through an equal number of graduations on either side of the zero scale; the weight in each pan is then the same. Let us now see how the weights are to be read; this should be done from the box, reading the empty spaces. In the case in point these are 10 + 5 + 2 = 17. Against "weight of crucible," write this number in the note book. Next read off the decigram weights; there are empty, 0.5 + 0.2 + 0.1 = 0.8; write .8 after the 17. The centigrams come next, they are 0.05 + 0.02 + 0.01 + 0.01 = 0.9; write 9 after the 8. The milligrams and fractions of a milligram are to read off from the rider; in the present instance the rider stands at 0.0054 grams, 54 must therefore be written after the 9. The whole figure will then read:—

"Weight of crucible = 17.8954 grams."

Having thus read the weight from the empty spaces in the box, next take the weights out and check the reading off as they are returned to their places. This double reading greatly reduces the chances of error in recording the weight of the substance. After a little experience in weighing, and thus getting to know the capacity of the particular balance used, the student should test his balance in order to ascertain the value of each graduation of the index scale. To do this put the rider on the 5 milligram mark, cause the beam to vibrate, and notice how far on either side of the zero it swings. Alter the position of the rider until the beam swings from the zero to the 10 on the one side; note the position of the rider. Suppose it to be on the 5, then 10 divisions of the index scale = 5 milligrams, and 1 division = 0.5 milligram. This value will only be approximately the same when the pans are loaded, but still sufficiently near to save the time of weighing. Thus, suppose 3.5 grams have been placed in the pan, and the index vibrate 10 to the right and 8 to the left, there is no need to successively try the 0.2 and other weights down to the 0.01, but the rider may at once be put on the 1 milligram mark, and will be found to be very nearly in its right place. One or two trials will then find the exact weight. The 1 is found in this case by taking half the difference between the vibrations on each side; this will often apply, even though the balance does not swing quite to the ten; thus, the distances indicated might be 9 and 7. The beam should, however, be always caused to swing freely, as it makes a long oscillation in the same time as a short one. It will be noticed that, so far, the right-hand side only of the rider scale has been referred to; the left is also frequently convenient. Supposing that, with the 3.5 grams just mentioned, the index had vibrated the two extra degrees to the left, this would have indicated that the substance weighed about 1

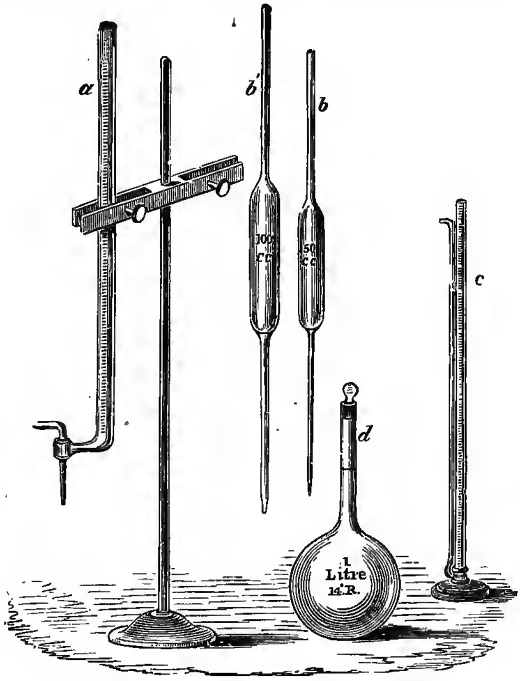


Fig. 72.—Various Measuring Apparatus.

milligram less than 3.5; to put this weight in would require the removal of the 0.5, and the placing of the 0.2, 0.1, 0.1, 0.05, 0.02, 0.01, 0.01, on the pan, and the rider at the 9 milligram mark. The same result is produced by placing the rider on the 1 milligram mark to the left. When the rider is on the left side of the beam, the weight it represents must be *subtracted* from that in the right-hand pan.

The operation of weighing has been described at full length, because it is the foundation of all quantitative analysis; these operations are, however, much shorter in practice than they appear on paper. The genuine chemical student will never forget that his balance should be carefully, intelligently, and even lovingly used.

In addition to the two balances and set of weights already described, the student will need another set of weights, ranging from 10 milligrams to 200 grams.

617. Apparatus Employed for Measuring Purposes.—These include measuring flasks, burettes, and other appliances.

618. Burettes and Floats.—Fig. 72 on page 469, is an illustration of various forms of measuring apparatus. The instrument marked *a* is termed a burette, and is used for the purpose of accurately measuring small quantities of liquid when delivered. There is at the bottom a glass stop-cock; the tube is graduated throughout. The most useful size of burette is that holding 50 c.c.; such an instrument is graduated in 500 divisions; these are numbered at each c.c., from the top downwards. In using the burette it is first cleaned, and then rinsed with a little of the solution with which it is to be filled, then filled up almost to the top. When a long and narrow tube, such as a burette, contains a liquid, the top is not exactly level, but is always slightly curved, with, in the case of water and aqueous solutions, the concave surface upwards. It is customary, in comparing the height of a liquid with the graduation marks, to read from the bottom of this curve, or "meniscus," as it is termed. The next thing is to run the liquid out through the stop-cock until the zero mark is reached. Fix the burette upright in the burette stand, and place the eye level with the zero graduation, then turn the stop-cock carefully, and let the liquid run out until the bottom of the meniscus exactly coincides with the zero line. The burette is generally used for the purpose of running a liquid into a solution until some particular change takes place, then the height of the reagent in the burette is again read off, and the quantity that has been used determined. So when the change, whatever it may be, is complete, again bring the eye level with the bottom of the meniscus, and read off the graduation with which it coincides.

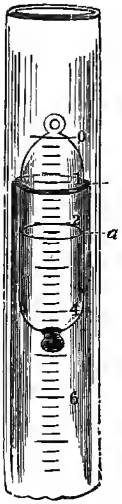


Fig. 73.—Erdmann's Float.

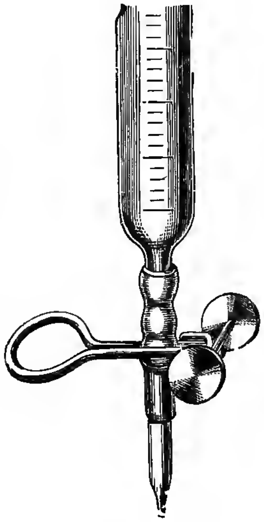


Fig. 74.—Mohr's Burette, with Spring Clip.

Accurate reading of the burette is much assisted by the use of "Erdmann's Float"; this little piece of apparatus, which is shown on page 470, (Fig. 73), consists of a piece of glass tubing of such a size as to be able to slide readily up and down within the burette. The tube is closed at both ends, so as to form an elongated glass bulb, which contains a small quantity of mercury. Around the float a single line, *a,* is marked with a diamond. When using the float it is dropped in the burette, and the line around it brought to agree with the zero mark at starting, and afterwards the height is read from the line on the float. A form of burette very convenient for general use is that known as Mohr's; it differs slightly in shape from that figured in the preceding illustration. Mohr's burette is made either with a glass stop-cock, or else with a glass jet fastened on with a piece of india-rubber tubing, and so stops the burette. The flow of the liquid is regulated by means of pressing the two buttons, shown, between the finger and thumb. The figure shows only just the lower end of the burette. The glass stop-cocks of burettes and other instruments should always be slightly greased, so as to prevent their sticking. If a burette is likely to be put aside for some time, it is well to withdraw the stop-cock altogether, and put it away separately, or a small slip of paper may be inserted between the plug of the stop-cock and its casing.

619. Pipettes.—Turning once more to Fig. 72, there are two instruments marked *b, b*; these are pipettes, and are used for delivering a definite volume of any liquid; the capacity of the two figured is respectively 50 and 100 c.c. In the tube just above the bulb there is a mark (not shown in the figure), which indicates the point to which the pipette must be filled. When using the instrument, place the lower end in the liquid to be measured, and suck at the upper until the liquid rises above the graduation mark, then stop the upper end with the tongue; next quickly substitute the tip of the finger for the tongue, without allowing the liquid to run out. This requires some little practice, but repeated trials overcome any difficulty at first experienced. Next raise the finger *very slightly* until the liquid begins to run from the lower end; let it do so until the bottom of the meniscus coincides with the graduation mark, then hold the end of the pipette over the vessel into which the liquid is to be poured, take away the finger and let the tube drain. When the highest degree of accuracy is required, the pipette should always be emptied in precisely the same manner. A good uniform method consists in holding the pipette vertical and allowing it to discharge its contents by gravity. When the main stream has stopped, hold the instrument in the same position until three drops have fallen, and then remove it. The pipette, if correctly graduated, will thus deliver the exact amount of liquid marked on it. The following are convenient sizes for pipettes: 2, 5, 10, 20, 25, 50, and 100 c.c. One 10 c.c. pipette will be required graduated throughout its whole length, somewhat like a burette; it is, in fact, used for very much the same purpose.

620. Measuring Flasks.—The only other piece of apparatus that need be explained at present is the graduated flask, *d,* Fig. 72; this has also a mark round the neck showing the graduation line. The same remarks apply to its use as those already made in reference to the other pieces of measuring apparatus.

Other pieces of apparatus required, with the methods of using them, will be described as occasion for their employment arises.

CHAPTER XXI.

COMMERCIAL TESTING OF WHEATS AND FLOURS.

621. Wheat Testing.—The simplest and most direct commercial tests that can be made on whole wheat are its weight per bushel, weight of 100 grains of average size, and percentage of foreign seeds, dirt or other extraneous matter. Other tests are best made on the finely-powdered whole meal of the grain.

622. Weight per Bushel.—This operation is so familiar to all millers that an explanation of it is scarcely necessary. As is well known, there is a special piece of apparatus sold that is made for the purpose. A cheap and efficient substitute for this may easily be prepared and used where a student has such a balance as the coarser one previously described. Get a coppersmith to make a cylindrical measure about 3 in. in diameter and 3 in. deep. Procure from a dealer in chemical apparatus a counterpoise box; these are brass boxes with lids which screw on. Put the empty measure on the one side of the balance and the counterpoise on the other, fill with shot until it exactly balances the measure. Next fill the measure exactly full of distilled water, *level with the brim,* and again weigh, always placing the counterpoise on the weight pan. The weight in grams of the water held by the measure represents its capacity in c.c. Now the weight of a bushel of water (= 80 lbs.), and that of the water contained in the little vessel, are always constant; and, as the weight of the water the vessel contains is to the weight of the wheat that is being tested, so is the weight in pounds of a bushel of water to that in pounds of a bushel of the wheat. Expressing this in the usual way we have—

As weight of water held by vessel : weight of wheat held :: 80 : lbs. per bushel;

$$\text{or, } \frac{80 \times \text{weight of wheat held}}{\text{weight of water held}} = \begin{array}{l}\text{weight of wheat in}\\ \text{pounds per bushel.}\end{array}$$

Now for any particular vessel the weight of water it holds is always constant, so that 80 in the upper line, and the weight of water in the lower, may be reduced to a single factor, and the weight in pounds per bushel at once determined by multiplying the weight of grain, held in the measure, by that factor. Suppose that the capacity of the vessel is 200 c.c., then $\frac{80}{200} = 0.4$ is the factor, and the weight of wheat in grams held by the vessel would simply have to be multiplied by that figure. In taking weights per bushel the little measure should be carefully filled, and then struck level by means of a pencil or other round piece of wood.

623. Weight of 100 Grains.—For this estimation it is important that the grains selected shall represent the average sample: if they are simply picked up one by one out of a heap, the weight is almost certain to be in excess of the true average; for a person under these circumstances almost invariably unconsciously selects the largest grains. To obviate this, fold a strip of paper so as to form a V-shaped gutter; take a handful of the wheat and let it pour in a small stream along the length of this gutter.

Then commence at the one end and count off the 100 grains, taking each as it comes. Weigh on the pan of the balance and enter the weight in the note-book.

624. Percentage of Foreign Matter.—The foreign matter in a sample of wheat may consist of other seeds, or possibly dirt or stony substances. Where it is only the former, a portion of the grain may be weighed off, and foreign seeds separated by hand-picking, and again weighing. The methods adopted for the removal of dirt must depend on the character of that present in the particular sample. Light, dusty, non-adherent matter may be removed by sifting or winnowing by means of an air current, and then weighing the residual grain. Adherent dirt will probably require washing of the wheat, and with this operation, the absorption of water by the grain comes in as a disturbing factor, for which provision must be made. The following is a convenient method of estimating dirt by the process of washing. From a fair sample of the wheat a convenient quantity is weighed off for the estimation; 20 grams is usually a good workable quantity. A duplicate 20 grams is weighed off and placed in the hot-water oven in order to determine moisture (see subsequent paragraph 627). The lot to be washed is put in a wide-mouthed bottle, and shaken up with water; the water is then poured on a fine sieve. This operation is repeated until the grain is clean. The wheat is then poured on to the sieve and examined in order to see whether there are any pieces of stone or other matter which ought to be picked out. Finally the drained wheat is transferred to a dish and also placed in the hot-water oven. Both it and the portion for moisture determination are allowed to remain until the weight is constant (say over the night), which is then noted. The difference between the two figures is the amount of dirt removed by washing. An example will make this clear.

Wheat taken for moisture, 20 grams,		
Weight after drying	17.54	grams.
Wheat taken for washing, 20 grams;		
Weight after washing and drying ..	16.06	„
Weight of dirt removed	1.48	„
Multiply by	5	
Amount of dirt in samples	7.40	per cent.

625. Grinding of Samples.—The fine whole meal for other determinations is best obtained by passing the wheat through a combined grinding and cutting mill, of which a very convenient form is that known as the "Enterprise" drug mill. An ordinary coffee mill might answer the purpose, but most likely would not cut up the bran sufficiently fine. The process adopted is as follows:—The mill is set as fine as it will run without clogging. (It need scarcely be mentioned that every part must first be thoroughly cleaned.) The wheat is then poured in the hopper and run through as rapidly as possible. The grist is next put into a fine sieve, about 20 or 24 meshes to the inch, and sifted. The bran is returned to the mill, and run through and again sifted; this operation is repeated on the coarser particles until the whole of the meal has been thus sifted. Care must again be taken at the end to clean every particle out of the mill and add it to the meal; this is essential, because the latter particles are more branny than the former. The meal is next stirred up thoroughly, and then stored in a tightly corked or stoppered bottle. In this way a whole meal is obtained, which of necessity is an exact representative of the grain. It may be asked whether the wheat should be cleaned in any way previous to grinding for analysis. The answer to such a question is that this must depend on the purpose for which the analysis is required. An analysis made for the purpose of buying or selling by should be performed on a sample representing the bulk of the parcel of grain in question; it should therefore be in no way cleaned or washed. When a miller requires to know the analytic character of a variety of wheat in the cleaned state, the analysis would obviously be made on the sample after cleaning. Undoubtedly the safest plan is to analyse the sample exactly as collected, unless the analysis is made for some special purpose. If a clean wheat is analysed the weight of cleaned wheat obtained from a definite weight of the uncleaned wheat should first be ascertained.

626. Experimental Test Mills.—The best general mode of testing wheats is that of first reducing the same to flour, and then testing the flour. With this end in view, the larger mills are frequently fitted with small reduction plants by which an experimental quantity of wheat may be reduced to flour, and this tested before the *whole* of the wheat is ground. The plant for this purpose may be of various sizes, from a fairly complete small roller mill installation to a specially made machine for reducing purposes, the different separations being made by hand. In this connexion see the description of Tattersall's special milling plant in Chapter XXVII on Routine Mill Tests. On the flour thus obtained, determinations may be made of such kinds as are employed on flour produced during the ordinary course of manufacture. It does not follow that the experimentally-made flour will be equal in every respect to that obtained in practice on the larger scale; but usually the results are sufficiently nearly comparative with each other to afford valuable information. The practical miller will naturally make allowances for the milling peculiarities of the wheats he may be thus examining.

With a mill of this kind, the percentage yield of straight flour, bran, and other offal, obtainable from each particular sample of wheat may be determined.

627. Moisture Determinations.—These may be made either on the ground meal from grain or the dressed flour. They are sometimes made on the whole wheat, but with this there is the objection that the unbroken grains lose moisture somewhat slowly. In view of the wide extension of the use of conditioning and analogous appliances and processes in modern milling, a check on the moisture of the wheat and also on the flour, bran, and other products has become of considerable importance. The percentage of water or moisture is usually found by weighing out a definite quantity of the flour or meal in a small dish, and then drying in the water oven until it no longer loses weight. When a number of samples have to be assayed, some regular method of procedure is necessary. The following method may be adopted:—

Procure from the apparatus dealer one dozen selected glass dishes, 2½ in. diameter. Mark these with the numbers 1 to 12 on the sides with a writing diamond. Have a little box made in which to keep these dishes. The box should have a shelf, supported a little way from the bottom, containing a series of separate holes, one for each dish, so that they may be kept without danger of breakage. Clean and dry each dish, and then weigh it carefully; enter the weights in the note-book, and, previous to using each dish, test its weight. This may be done very quickly, as the weights are already approximately known. It will be found that, if used with care, the weight of the dishes will remain constant, within some four or five milligrams, for a considerable time. Time may be still further economised by having a series of counterpoises made for the set of dishes. These consist of little brass boxes in the shape of weights, the tops of which can be unscrewed. Brass counterpoises of this description can be readily obtained. Have engraved on the top of the counterpoises a series of numbers corresponding to those on the dishes; clean the counterpoises and dishes thoroughly, and balance the one against the other in the following manner:—Place No. 1 dish in the left-hand balance pan, and the corresponding counterpoise in the other, together with its cover. Fill up the counterpoise with shot until it is as nearly as possible of the same weight as the dish, then add little shreds of tinfoil until the two exactly counterbalance each other; finally screw the lid and box part of the counterpoise together. Proceed in exactly the same way with all the dishes. In this case the shelf of the box for the dishes should also have little holes cut in it for the counterpoises, so that each may be kept immediately in front of its particular dish. Having a set of counterpoises, before using each dish test it on the balance against its counterpoise, and if necessary adjust the weight with the rider. As the dishes gradually become lighter through use, the rider will have to be placed on the left-hand or dish side of the balance. In case the balance is one which is only fitted with the rider arrangement on the right-hand side, the dish may, if wished, be placed on that side, and the weights on the left in weighing; this, however, is liable to lead to confusion and mistakes in reading the weights. As the dishes grow lighter, their weight against the counterpoise is really a minus quantity, and should be entered as such in the note-book. For a long time the difference between the two is inappreciable, but still, for the sake of accuracy, the test should always be made. When the dish and counterpoise differ more than .005 gram, the latter should be readjusted. Having a number of determinations to make, weigh out exactly 10 grams of each flour in a dish, then place them in the hot-water oven and allow them to dry for 24 hours; at the end of that time the water will be expelled. Take out the dishes, allow them to cool in a desiccator; and weigh as quickly as possible. As the weight of each is approximately known, put the larger weights on the balance pan before taking the dish from the desiccator. After weighing, return the dishes to the oven for another hour, and again weigh; the two weighings should agree within a milligram. Dry flour is very hygroscopic; that is, it absorbs moisture with great rapidity. This is noticeable during weighing, for a sample will often gain while in the balance as much as five milligrams. The student will at first, for this reason, get his weights too high. The best plan is to put on the rider at a point judged to be too high, and then at each trial bring it to a lower number until it is found to be at one at which the dish is the heavier. Then take the lowest figure known to be above the weight of the dish, for if the rider now be moved upwards, the dish will often be found to gain in weight just as rapidly as the rider is moved upward. Before the dish is removed from the desiccator for the second weighing, put in the pan the lowest weights before found to be too heavy. After a time the student will find that he can get his two weighings to always practically agree; he may then, but not till then, dispense with the second weighing: It is evident that the flour after being deprived of its moisture will weigh less; the weight taken, therefore, less the weight of dried flour, equals the moisture, this, when 10 grams are employed, multiplied by 10 gives the percentage.

There are now made flat porcelain numbered dishes for milk analysis, and these may if wished be used instead of glass dishes for moisture determinations. Another convenient form of dish is that of polished nickel made in the flat shape; these latter possess the advantage of being unbreakable.

628. Hot-Water Oven.—These ovens are usually made of copper, and are of the appearance and shape shown in Fig. 75. The oven consists of an inner and outer casing, with a space between them about an inch in thickness; the top, bottom, two sides, and back, are therefore double. This space for about half the height of the oven is, when in use, filled with water, which is kept boiling by a bunsen flame placed underneath. Anything placed in the oven is thus kept at a temperature of from 96-100° C., but, while there is any water within the casing, never above the latter temperature. In order to prevent the oven boiling dry, a little feed apparatus is a convenient attachment. This usually consists of a copper vessel open at the top, and communicating by means of a pipe with the water space of the oven. Through the bottom of this vessel is passed a piece of glass tubing, the top of which reaches to the height at which it is desired that the water shall remain in the oven. This glass tubing is kept in its place by a piece of india-rubber tubing, which, while making a water-tight joint, allows the tube to be slidden up or down as wished. A small stream of water is led into the feed apparatus; this feeds the oven, and the overflow passes out through the glass tube, which should either stand over, or be led into, a drain.

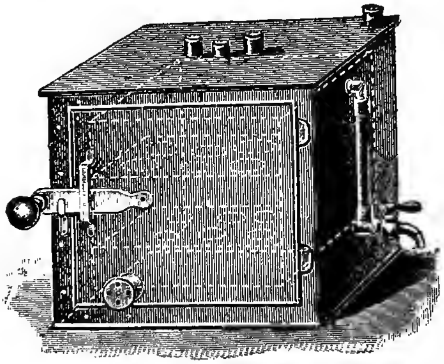


FIG. 75.—Hot-Water Oven.

Another very good plan is to have fitted to the top of the water oven an inverted Liebig's condenser, through the outer casing of which a stream of cold water is passed. The steam from the boiling water in the casing is then condensed by the condenser, and returned to the oven. The oven, having been once filled, will not need replenishing for a considerable time, as the loss of water is very little. The condenser should be made of brass or copper tubing; the inner tube about ⅝ in. in diameter, and the outer 1¼ in.: the length should be from 24 to 30 in. The cold water should enter the jacket at the bottom. When a condenser is used, the oven should also be fitted with a glass water gauge, to indicate the height of the water as shown in the figure. With this arrangement the oven may be filled with distilled water, and so loss of heat by the formation of crust be prevented.

Where time is an object, it is convenient to use an oil oven instead of one filled with hot water. The oven is similar in construction, but the jacket is filled with oil, and the temperature raised for wheat or flour drying to 105-110° C., being regulated by adjusting the burner, or by means of an automatic regulator.

629. Vacuum Oven.—In estimations of moisture for milling purposes, speed is almost always of the utmost importance; the authors have therefore designed and used with success a special form of vacuum oven for such determinations. The oven, Fig. 76, is of circular shape with flat bottom, and consists of an inner casing, *a, a,* and an outer jacket *b, b,* of copper. The diameter of *a, a,* may be from 10 to 12 in., and the internal height about 5 in. The space between the casing and jacket should be not less than 1 in. At *c* is attached a small water gauge. A return condenser is fixed as shown at *d, d*. By means of a burner fixed under the oven the temperature of the water in the jacket is maintained at 100° C. Or if wished, a solution of potassium carbonate may be employed; this boils at a temperature above 100° C. and depending on the degree of concentration of the solution. A drawback is that the salt slowly attacks the metal of the oven. Or an organic liquid such as toluol, boiling at 107° C., may be used. With this, however, care must be taken, as the boiling liquid is inflammable. The advantage of the higher temperature is the more rapid drying capacity of the oven. At *e* is fixed a pipe leading to a Körting or other efficient vacuum pump. The open end at *e* is turned up so as to prevent the inrush of air from impinging on the contents of dishes in the oven. At *f* a tap is placed, by which air can be admitted into the oven; on the opposite side *g* is shown a small Bourdon vacuum gauge. The upper part of the oven is drawn into an opening about 6 in. internal diameter, terminating in a flange the face of which is turned and ground perfectly true at *h*. On this rests a gun-metal lid, *i*, also faced true. At *j, j*, are hinged screw clamps by which the lid is securely screwed down to make an air-tight joint with the upper flange of the oven. In use the oven is made hot by a burner arranged underneath, preferably of the

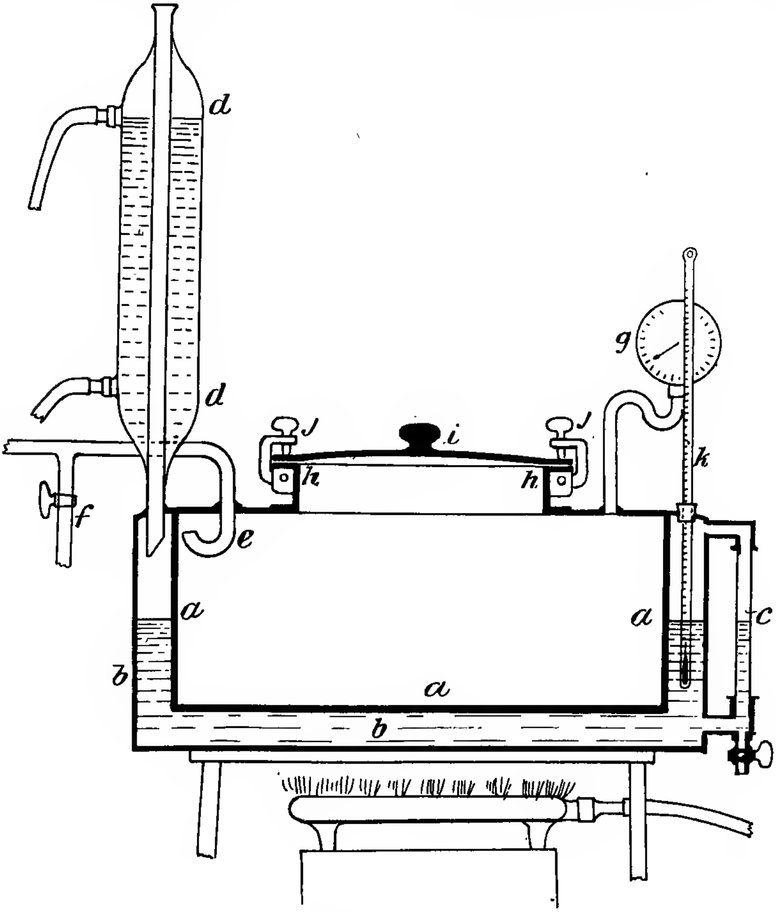


FIG. 76.—Vacuum Oven.

ring type. Flat nickel dishes are most suitable for the flours or meals. These are placed in the oven and then the lid is fixed in position. In order to make the joint, the faces of the flanges are smeared with a luting mixture of rubber dissolved in naphtha, such as is used for repairing pneumatic tyres, or a rubber ring may be used. In this latter case the ring and the faces of the flanges should be well blackleaded. The top at *f* is closed and the vacuum pump started, and kept at work so as to maintain a good vacuum as shown by the gauge. Drying is exceedingly rapid and thorough with the flat dishes in immediate contact with the flat bottom of the oven. The minimum time for complete drying should be ascertained by an actual test; after which, provided the vacuum is kept up, the dishes with their contents may simply be dried for the requisite time and then weighed. To reopen the oven the pump is turned off, and then the tap *f* carefully opened to admit air. The clamps are then unscrewed and the lid slid off.

630. **Effect of Humidity of Air on Moisture of Flour.**—Flour is exceedingly hygroscopic and absorbs or loses moisture, according to whether the atmosphere is damp or dry, with great readiness. Richardson examined a series of flours immediately on coming from the mill, and again after being exposed to the atmosphere for a day, with the following results:—

	Original Moisture.	Gain or Loss.	Second Day.
No. 1.	9.48	+0.65	10.13
„ 2.	7.80	+2.15	9.95
„ 3.	7.85	+2.30	10.15
„ 4.	7.97	+2.15	10.12
„ 5.	13.69	—3.28	10.41

It will be seen that, notwithstanding the wide differences in percentage of moisture on the first day, they had, at the end of the second, become practically equalised. Richardson next allowed these flours to remain exposed to the atmosphere for 16 days, making during that period 15 determinations of moisture. In one and the same flour during that time variations of nearly 5 per cent. were observed. In the following table the results are expressed in weight in lbs., which 100 lbs. of the original flour would have assumed under the conditions:—

No.	Original Weight.	Original Moisture.	Highest Weight during 16 days.	Lowest Weight during 16 days.	Amount of Variation.
1.	100 lbs.	9.48	102.88 lbs.	99.53 lbs.	3.35 lbs.
2.	100 „	7.80	104.87 „	100.00 „	4.87 „
3.	100 „	7.85	105.20 „	100.00 „	5.20 „
4.	100 „	7.97	105.95 „	100.00 „	5.95 „
5.	100 „	13.69	100.00 „	95.35 „	4.65 „

No. 1 of these flours was the well-known brand, Pillsbury's Best; it will be of interest to give the weight of this each time determined, and also the relative humidity of the air each day.

Date.	Weight of Flour.	Relative Humidity of Air.
March 7	100.00 lbs.	—
„ 8	100.65 „	46.4
„ 10	99.53 „	35.0
„ 11	101.73 „	59.0
„ 12	102.68 „	60.1
„ 13	99.88 „	34.0
„ 14	101.08 „	—
„ 15	101.53 „	48.2
March 17	100.38 lbs.	42.2
„ 18	101.88 „	59.5
„ 19	102.03 „	60.1
„ 20	102.48 „	55.6
„ 21	101.43 „	51.8
„ 22	101.68 „	51.1
„ 24	102.88 „	66.9

It will be observed that with an increased dampness of the air, the weight of the flour is also increased. Of course, in strictness, the weight of the flour is governed by the degree of humidity *prior* to the moisture determination, rather than that at the time the determination is actually made.

On exposing a sample of patent flour to an atmosphere kept absolutely saturated with water, it absorbed more than 26 per cent. of its original weight in 64 hours. The following table gives the weight at different intervals:—

Weight of flour taken	1.0000 grams.
„ after 35 minutes	1.0285 „
„ „ 18 hours	1.0930 „
„ „ 22 „	1.2005 „
„ „ 42 „	1.2405 „
„ „ 64 „	1.2670 „

These variations in weight of which flour is capable go far toward explaining discrepancies in water-absorbing power, and yield, of laboratory samples.

631. Gluten Determinations.—The strength of flour has been amply discussed in a previous chapter, in which it is shown that it largely depends on the quantity and character of the insoluble proteins contained in the flour. In a crude form these are obtained in the well-known washing process for gluten. One great objection to the gluten test is the difficulty of knowing precisely when the whole of the starch has been removed, and then stopping short of washing away any of the gluten itself. In many flours the gluten begins to disintegrate and wash away before the whole of the starch disappears. With some little experience the same worker can get concordant results, but this is not invariably the case with two workers testing against each other; one will then frequently throughout a whole series uniformly get higher results than the other. As, therefore, considerable differences may exist in the percentages of crude gluten obtained, both in the wet and dry state, it is recommended that in addition the "true gluten" or protein matter be also determined by a direct nitrogen estimation. Even when there are marked discrepancies in the crude gluten as obtained by washing, the true gluten varies only within comparatively narrow limits.

As an index of strength, it is recommended that the following estimations be made:—Percentage of gluten wet and dry by the washing-out process, and of true gluten by nitrogen determination on the dry gluten; all of these to be calculated on the whole flour. Appearance and physical character of the gluten to be noted. Percentage of total proteins in the whole flour.

632. Gluten Extraction.—One of the most important points is that a uniform method is always adopted. The following is a very convenient mode of working. Thirty grams of the flour should be accurately weighed and transferred to one of Pfleiderer's small doughing machines (made especially for the purpose). To this should be added in the machine 15 cubic centimetres (=15 grams) of water from a graduated pipette. The whole should then be thoroughly kneaded, receiving 100 revolutions by the counter after the flour and water are first roughly mixed. (While the machine is exceedingly convenient, the dough may as an alternative be made by hand.) From the resultant dough one or two portions of exactly 15 grams each should be accurately weighed and then transferred to a small glass containing sufficient cold water to keep them entirely submerged in which they must be allowed to remain for exactly an hour. (The second piece is only to be weighed off in event of a duplicate being required.) The weighed portion of dough contains exactly 10 grams of flour, and should be washed in the following manner:—Prepare some water at a temperature between 70° and 80° F., and partially fill a clean bowl with same. For reasons before given the water must be ordinary tap water, and not distilled water. Wash the lump of dough by kneading it gently between the fingers in the water, using no muslin or other enclosing substance. The starch is gradually washed away, and the remaining dough acquires the consistency and characteristic feel of gluten. Take care that no fragments are washed off the main lump; and after the gluten is approximately freed from starch, place it aside on a clean surface of glass or porcelain: let the washing water settle, and decant it very carefully through a fine hair sieve. Should there be any fragments of gluten on the sieve, pick them up with the main piece and do the same with any remaining in the basin. Take some more of the tepid water and repeat the washing some little time longer; change the water about two or three times, with the same precaution against loss as before. The last washing water should remain almost clean. The gluten may now be taken as pure, freed as far as possible from adherent moisture and weighed.

In the case of Hungarian and certain other flours of very high water-absorbing power, it is sometimes advisable to make a slacker dough for gluten extraction than that just described. For this purpose add 20 c.c. of water to the 30 grams of flour, and take 16.66 grams of the dough for each estimation. This weight contains, as before, exactly 10 grams of flour. If preferred, 10 or 20 grams of flour may be weighed off and made up into a dough with water direct for this estimation.

When it is intended to determine the gliadin in the gluten, 30 or 33.33 grams of dough should be taken for washing purposes instead of 15 or 16.66 grams. The washing operation should be conducted as before. The whole mass of gluten is then weighed and registered as wet gluten, after which it is separated into two halves by weight. One is dried for dry gluten, and the other is used for the gliadin estimation (see paragraph 677).

For the drying of the gluten, pieces of paper should be prepared beforehand in the following manner:—Take a sheet of cartridge or other stout paper and cut it up into small pieces 3 inches square. Place these in the hot-water oven and dry at 212° F. for two days. Take them out and allow to cool in a desiccator, and weigh them off rapidly to within a decigram. Mark the weight in pencil on the top left-hand corner of the paper . Keep a store of these in a clean box. If preferred, these may be obtained ready cut from a printer. They will then be found to be of just the same weight; and if two pieces be equally dried in the hot-water oven they will still counterbalance each other. This should be verified by an actual trial. When any number of glutens are being simultaneously determined, a blank piece of paper may be put in the oven with the glutens, and used throughout as a counterpoise when weighing them. If for any reason special accuracy is required, the paper should in each case be dried and weighed for each estimation.

Having weighed the gluten as above described, mould it between the fingers and notice its physical condition, whether tough and elastic, soft and flabby, or "short" and friable. Make a note of same. Mould it into a ball and place it on the centre of one of the weighed papers. On the one corner mark the date, and below, the name or number of the flour, with the weight of the wet gluten. Next place the gluten in the hot-water oven and dry at 212° F. until the weight is constant; then weigh to the decigram, subtract the weight of the paper, or weigh against the counterpoise piece, and express the result in percentages. The gluten adheres to the paper, and thus may be kept as a record of the flour.

To determine the true gluten, break up the crude dry gluten into coarse fragments, and estimate nitrogen by the Kjeldahl method, as described in Chapter XXIII. The percentage of the true gluten should be returned on the whole flour, and should be at least 80 per cent. of the crude gluten.

By means of the same process (Kjeldahl) determine the total proteins in the flour.

633. Extraction of Gluten from Wheat-Meal.—The meal may be weighed and made into a dough precisely as with flour; or if wished, 10 or 20 grams only may be weighed off and transferred to a basin, and then mixed with sufficient water to make a somewhat slack dough. This is allowed to stand as before for one hour under water. Instead of washing the dough direct in the bowl, it is preferable to first enclose it in a piece of either fine muslin or, preferably, millers' bolting silk. This must be held securely in order to prevent any loss of the dough, which must be held under water in the bowl and kneaded between the fingers until a fresh lot of water is no longer caused to become milky by the escaping starch. On opening the silk, it will be found not only to contain the gluten, but also the bran of the wheat, and these have to be separated from each other. With the harder wheats this is done without much difficulty, but in the case of those that are softer it is sometimes almost impossible to recover the whole of the gluten. After having washed out the starch, squeeze the water from the silk, and then open it out on a piece of glass. There will usually be one fairly sized lump of gluten; take this out and rinse it moderately free from bran in a basin of clean water, next squeeze it well together, then pick off any tolerably large pieces of gluten that remain on the silk, and add them to the main lump. After each addition again squeeze the piece together and rinse off any loose bran. The difficulty is now to gather together any particles remaining in the bran—these are often so small as to be scarcely visible. Take the mass of tolerably clean gluten and add to it a portion of the bran, roll them together with considerable force between the palms, and then wash off the bran. This process of rubbing together the main lump of gluten and the bran effects the removal of any little fragments of gluten by their sticking to the larger piece; which, in virtue of its adhesive property, picks them out from the bran, just as a magnet picks out iron filings from among those of brass. Treat the whole of the bran remaining on the silk in this manner; the result will be a lump of gluten still containing a little bran. With a hard wheat, however, the whole of the gluten will have been thus recovered; with the softer ones it is sometimes advisable to drain the water off the bran and again rub it all up with the gluten. In every case inspect the bran most carefully before throwing it away; the bran should also be rubbed between the fingers; this will often detect fragments of gluten that escape the eye. Having got the whole of the gluten together, wash it time after time until free from bran. This is a tedious operation, but one that can be performed by vigorous and careful treatment. Pour every lot of water on to the muslin in order to see that no gluten is lost. The washing must be continued until the gluten yields no turbidity to clean water.

The subsequent processes are performed on the wheat gluten precisely as with that from flours.

634. Water-Absorbing Capacity.—One of the best methods of determining the water-absorbing capacity of a sample of flour is by doughing it, and then judging by the consistency of the dough. The dough may be tested in this manner shortly after being made up, and again after an interval of some hours. A more or less accurate judgment is thus formed of the water-absorbing power of the flour when first made into dough, and also its capacity for resistance to the changes which take place in the constituents of flour while standing for some time in a moist condition. The unfortunate point about such determinations is, that judging by the appearance and stiffness of a dough is exceedingly uncertain: one person's own judgment is not at all times alike, and the difficulty is multiplied infinitely when an attempt is made to compare that of several persons. Again, there is the fact that for all purposes of exactitude it is essential that some means shall exist for expressing results in actual figures.

Finding the problem in this state, one of the authors devised apparatus, which had as its object the determination of water-absorptive power, and giving a numerical expression of the result. The starting point was to decide on some mode of expressing yield: the first idea was to make use of the number of quartern loaves of bread that could be produced from a sack of flour. But here the difficulty occurred that different bakers are in the habit of weighing their bread into the oven at different weights, to say nothing about the possibilities of different weights when the bread leaves the oven. Further, the use or non-use of "fruit" renders this method of considerable uncertainty. There is again the fact that some bakers work with slacker doughs than do others.

After considering several possible modes of expression, the decision arrived at by the authors was to give the quantity of water that a specific weight of the flour took, in order to produce a dough of definite and standard consistency. By almost universal consent the standard of weight of flour would, in England, be the sack of 280 lbs., while water can be conveniently expressed in quarts. The quart being the quarter of a gallon, and the gallon weighing 10 lbs., render it easy to convert quarts into either gallons or lbs. It will be noticed that the adoption of this standard does not touch on the contested question of loss of water in the oven. If preferred the tests may be made, and the results expressed in c.c. per 100 grams, *i.e.*, parts per hundred, or if wished lbs. of water per barrel, 196 lbs. of flour, may be adopted.

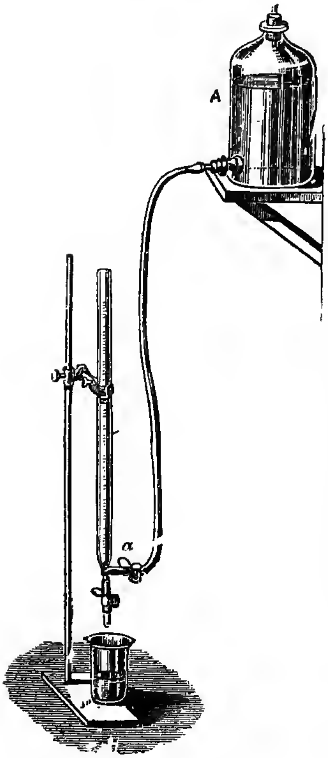


FIG. 77.—Burette, Arranged with Reservoir.

635. Water-Absorption Burette.—The operation of doughing resolves itself into taking any convenient quantity of flour and adding sufficient water to it to make a dough of normal stiffness and then calculating out the water employed into the proportion of quarts per sack. The simplest way of doing this is to fix on the quantity of flour, and then make a measuring instrument for the water ("burette" or "pipette"), which shall be graduated so that each division represents a quart of water per sack. Such a measuring instrument is the first part of the apparatus described; in using it, the flour is weighed out, and the quantity of water run in is at once read off, without any calculation whatever, as quarts per sack. The practical advantages of this method are evident, as from a small doughing test a baker can at once direct how much water is to be added per sack of any particular flour. The strength burette, together with the viscometer, is shown in Fig. 78: at the top of the instrument is the zero mark, between which and "40" there are no graduations; the tube is then graduated in single quarts down to 80 at the lower end. At the bottom a glass jet is attached by means of a piece of india-rubber tubing; this is normally kept closed by the spring-clip, but may be opened at will by pressing the two buttons shown, one on either side. In use, the burette may be held in the hand, but is preferably fixed in a burette stand. It may be filled either by pouring in water at the top, or by opening the clip and sucking it up through the jet.

It is important to bear in mind that if great exactness is required in doughing tests, the dough, when made, should have a definite temperature. It is recommended that for this purpose that of 70° F. be adopted. If possible, a flour-testing laboratory should stand permanently at as nearly as possible that temperature. Before starting a series of tests, the water should be adjusted to 70° F.: and the flours, if cold, allowed to stand in a warm room sufficiently long to give the same temperature when tested by the thermometer.

Where a number of flours are being tested, it is an exceedingly convenient plan to have a water reservoir attached to the burette; the whole apparatus will then appear as shown in Fig. 77.

In the lower part of the figure the burette is seen fixed in a stand. At *a* is a second tube opening into the burette above the clip; by means of india-rubber tubing, this second tube, *a,* is attached to a glass reservoir, A, which stands on a shelf above the level of the top of the burette. By means of a spring-clip at *a* the liquid in the reservoir is shut off from the burette. The burette being empty, open the clip *a;* the water flows from A upward into the burette; when the level coincides with the zero mark close this clip, and proceed to deliver the desired quantity of water by pressing the clip at the bottom of the burette. In this manner the instrument may be filled with great convenience and rapidity.

To test a flour, weigh out as exactly as possible one and a half ounces of the sample, and transfer it to a small cup or basin. Next fill the burette with water until the level exactly stands at the top graduation mark. Then place the cup containing the flour under the burette, and press the clip, allowing the water to run out until down to as many quarts as it is thought likely the flour will require. Then, by means of a stirring rod, or bone spatula, work the flour and water into a perfectly even dough; try, by moulding it between the fingers, whether it is too stiff or too slack: if so, dough up a fresh sample, using either more or less water as the case may be. Having thus made a dough of a similar consistency to that usually employed, read off from the burette how much water has been used. The figures will express, without any further calculation whatever, how many quarts of water the flour will take to the sack. It is well before judging the stiffness of the dough to allow it to stand for some time. The authors allow their doughs to remain an hour before testing them.

It is not safe to state from the doughing test alone how many loaves a certain flour is capable of yielding per sack, because different bakers, by working in different manners, do not get the same bread yield from one and the same flour. Each baker should therefore ascertain for himself by means of a baking test, working according to his own methods, how many loaves he obtains from a sack of any particular flour. He can then in the following manner arrange for himself a table showing the bread equivalent of the "quarts per sack" readings of the burette. To make this test, take a sack of flour and measure the quantity of water requisite to make a dough of the proper consistency. Then count the number of 2-lb. or 4-lb. loaves it yields on being baked. Suppose that the flour takes 70 quarts of water: then dough up a sample with the burette, using water to the 70 quart mark, and take dough of that stiffness as the standard. Any other flour of the same character which takes the same quantity of water to make a dough of similar consistency will turn out about the same yield of bread. Suppose another sample of flour takes 72 quarts of water, then it will make, neglecting the slight loss in working, 5 lbs. more dough (one quart of water weighs 2½ lbs.). Weighing the bread into the oven at 4 lb. 6 oz. per the 4-lb. loaf, every two quarts more water per sack means rather over another 4-lb. loaf produced. In exact figures the additional 5 lbs. of dough yield 4 lbs. 9 oz. of baked bread, or practically 4½ lbs.

In this easy manner, by this instrument, a baker may determine for himself, without any but the simplest mental calculation, and working according to his own processes, how much bread a particular flour yields. It is advised that every baker should for himself construct a table of results, based on his own method of working. To do this, let him, as suggested, make a trial baking, and find out how many quarts of water a sack of any one flour takes, and how many loaves it produces. Enter those figures in the table, then for every two quarts more add on 4½ lbs. of bread or 1⅛ 4-lb. loaves: for every two quarts less subtract the same amount.

636. The Viscometer.—In order to carry the water absorption problem a step further, it is necessary, not only to have made the dough, but also to devise means for mechanically determining its consistency. This is the more difficult, as different kinds of flour produce doughs of different character. Thus, a spring American flour will yield a dough whose essential characteristic is rigidity; a Hungarian flour yields a soft dough, but one which, nevertheless, possesses most remarkable tenacity. Any instrument for measuring the consistency of dough must take into account these two somewhat opposite characters, giving each its proper value. The resistance of the dough to being squeezed, and its resistance to being pulled asunder, must both be taken into account. The second part of the flour-testing apparatus consists of an instrument for definitely measuring the viscosity of dough. This is effected by forcing a definite quantity of dough through a small aperture, and measuring the time taken in so doing, the force being constant. The machine for making this measurement is termed a "Viscometer," literally, a measurer of viscosity. It is so arranged that, in doing the work of forcing the dough through the aperture, both the stiffness and tenacity of the dough are called into play as resisting agents. The consequence is that a very soft and tenacious dough may prove its viscosity to be as great as that of a stiff dough with comparatively little tenacity. Undoubtedly this is in keeping with the observed facts of baking, for, as is often said, certain flours will bear being made much slacker than others; that is, their tenacity as dough more than makes up for their comparatively little stiffness or rigidity.

The viscometer consists essentially of a cylinder, having a weighted and graduated piston, and an aperture through the bottom for the exit of the dough; the stiffer the dough, the more slowly does the piston descend. Since the first instrument was made a number of alterations and refinements have been introduced with the object of diminishing certain causes of error which were revealed on experiment. In its present form the instrument is affected in its working by the condition of the dough, and that only; further, it takes cognizance both of the tenacity and the rigidity of the dough. It is claimed for the viscometer that it affords a means of absolute measure of these two qualities of stiffness and tenacity. In certain cases where two doughs have been submitted to the judgment of bakers, and then tested by the viscometer, that judged the softer to the touch has been registered by the viscometer as the dough of greater consistency. The very simple explanation is that it is difficult to form an accurate judgment of tenacity by handling a small piece of dough. Flours which exhibit this particular combination of softness and tenacity are just those which bakers would say require to be worked slacker than others. Consequently, even in these instances, the viscometric measurement affords a valuable indication of the working water-absorbing capacity of the flour. Millers and bakers who have seen the apparatus at work endorse this opinion. In using the instrument, the dough is first put into the viscometer, and the time which the piston takes to travel between two of its graduations is noticed.

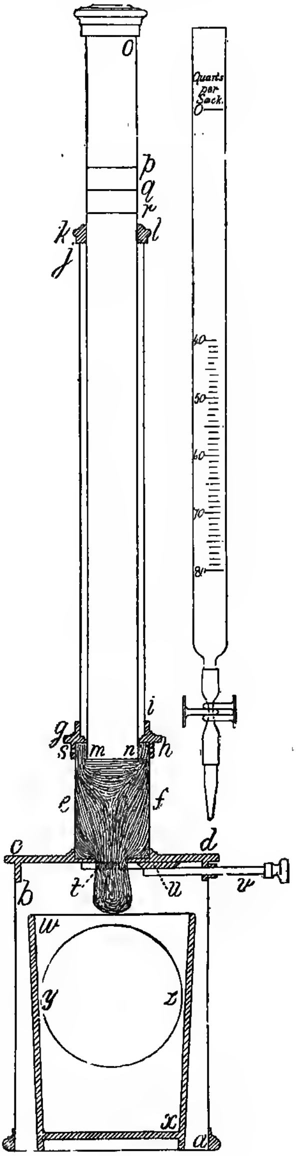


Fig. 78.—Viscometer and Strength Burette.

Fig. 78 is a sectional drawing of the viscometer, about one-third the actual size of the instrument. The lower part, *a b*, is a cylindrical base, through which are two lightening holes, marked *y z*. The cylinder, *e f*, and flange, *c d*, are cast in one piece; *c d* has a collar, turned down to fit inside *a b*, the edge of *c d* is milled. Through the bottom of the cylinder is a hole, marked *t;* the upper edge of this hole is rounded off, in order that no cutting edge will be presented. This aperture may be opened or closed at will by the cover, *u*, which slides between a pair of guides, and may be drawn in or out by the rod and milled head, *v*. The piston, *m n*, consists of a disc of gun-metal, the lower edge of which is rounded; this piston is attached to the bottom of a trunk, *m o*, the diameter of which is about one-sixteenth of an inch less than that of the piston. This piston trunk passes through the cylinder cover, *g h;* in the top of this cover is screwed a tube, *i j*, carrying at its upper end a collar *k l*. Both this collar and the cylinder cover, *g h,* are bored to exactly fit the trunk of the piston. The cylinder cover tube, *i j,* and collar, *k l,* therefore together act as a guide for the piston, allowing it to slide steadily up and down with the minimum of friction. The bottom of the cylinder cover fits over the top of the cylinder, and is secured in its place by a pair of studs and bayonet catches, *s h.* On the upper part of the trunk are three lines, *p q r,* the distance between each pair being three-eighths of an inch. This trunk is loaded inside in order to give it the requisite weight. With the exception of the piston, *m n,* the instrument is throughout constructed of brass.

637. **Method Employed in Using the Viscometer.**—It is first necessary to fix on a standard of stiffness for doughs: that adopted by the authors is such as allows the piston of the viscometer to fall from mark *p* to mark *r* in 60 seconds. As such doughs are slacker than those employed for many purposes, a stiffer standard may, if wished, be selected; in such a case the readings may be taken, if desired, when the piston has made half its stroke, that is, has travelled from *r* to *q* instead of the whole distance, *r* to *p.* Each individual user of the instrument may thus determine on a standard for himself.

Whatever standard is selected, whether the 60-seconds' standard employed by the authors, or another, weigh out one and a half ounces of flour, add water from the strength burette, and dough up the sample as before described, using a quantity of water, which, as well as can be judged, shall give a dough of standard consistency. The dough may be mixed by hand in a basin, but the authors strongly recommend the use of one of Pfleiderer's small doughing machines made specially for testing purposes: these have the great advantage that they mix the dough thoroughly, and with absolute uniformity. The machine is made with water-tight bearings, and is fitted with a revolution indicator by which the number of turns given to the handle are registered. Place the flour and water direct in the machine, and turn the handle so that the upper edges of the blades approach each other. When the flour and water are roughly mixed, scrape down the sides of the machine by means of a small spatula: note the position of the revolution indicator, and give the dough fifty revolutions. When sufficiently mixed, take the dough from the machine and set it aside in a small glass tumbler, or other vessel, for one hour. Cover over with a glass plate in order to prevent evaporation. When examining a number of samples, dough them up one after the other for an hour, and then come back to the further testing of the first one, and take them in rotation.

Having thoroughly cleaned the cylinder and piston of the viscometer, fill the cylinder with the dough to be tested; to do this, slightly open the bottom aperture and push in the dough through the top, by means of a stout spatula. In this way fill the cylinder completely, taking care that there are no air spaces; shut the aperture, *t,* and then, holding the cylinder horizontally in the left hand, put on the cylinder cover, the piston being at the top of its stroke. Secure it by means of the bayonet catches, and stand the cylinder squarely on the base, *a b.* Arrange a vessel, *w x,* to receive the dough as forced through the instrument. Next have ready a watch with seconds' hand (a chronograph is the most convenient thing, if one happens to be in possession of the worker); pull out the milled head, *v,* the piston begins to descend. As soon as the line *r* coincides with the top of *k l,* note the time, or start the chronograph:

note again when the line *p* descends to *k l*, and observe how long the piston has taken to travel this distance. If exactly sixty seconds, or whatever other standard has been selected, the dough is of the standard consistency, and the quantity of water used is that required by the particular flour to make a dough of the standard stiffness. Feel the dough with the fingers and see, especially, whether it seems hard or soft. A soft dough, which nevertheless goes through the machine slowly, must possess great tenacity. Such flours have almost invariably high water-retaining power. The tests having been made, turn back the bayonet catches, and withdraw the cylinder cover, piston, and guide from the cylinder. Remove the dough from the piston, and clean out the cylinder by means of a spatula. In handling the piston be careful not to hold it with the cover end uppermost, as the piston rod then slides backwards, and is stopped by the piston coming violently in contact with the cover. The piston being thin is liable by rough usage in this way to be forced off the rod. When the instrument is done with, the cylinder should be soaked in water, so as to remove any traces of dough that might clog the valve at the bottom.

Having described the mode of using the instrument, its action on the dough may now be examined. In the first place, the lower edge of the piston and the upper one of the aperture through the cylinder bottom are both rounded, therefore the dough is not subjected to any cutting action. In the next place, the piston during its descent meets with no resistance whatever except that due to the dough itself; as it passes *down* through the hole in the cylinder cover it is impossible for the dough to find its way *up* through that opening against the downward movement of the piston; consequently, there is no clogging whatever of the moving parts of the apparatus. The dough, in order to make its way out, has to alter its shape so as to pass through the small hole at the bottom, consequently its rigidity is here taken into account. At the end of the stroke, the piston is found to have pushed out a plug of dough from the centre of the cylinder, leaving a ring of dough standing round its outside. To force out this plug, the piston must have torn away these particles of dough from the annulus (ring) of dough left standing. Hence it is that this apparatus registers so thoroughly the tenacity of the dough as well as its rigidity. By shading the dough in the figure an attempt has been made to indicate the probable lines of movement of the dough as the piston passes downwards. An inspection of the drawing of the viscometer, and a study of its principles, show that it is the condition of the dough, and that only, which can possibly affect the speed at which the piston descends.

In practice it is well to have at least two tests made on the same flour with the viscometer. When the approximate water-absorbing power is known, these may well be taken at 2 quarts below and 2 quarts above this point respectively. Having obtained a pair of piston readings, one above and the other below the sixty seconds (or other predetermined) standard, the actual quantity of water corresponding to the standard may be calculated in the following manner:—For entering the tests it is recommended that a book be procured ruled both ways of the page: the water-absorption results should then be entered as shown in Fig. 79, page 489. Supposing 70 quarts to have run through in 90 seconds, and 72 quarts in 50 seconds, then on drawing a line connecting these two points, the place where it crosses the horizontal line marked 60 in seconds, will give the water absorption in quarts. Thus referring to Flour No. 2, Fig. 79, the 72 quart dough ran through in 86 seconds, and the 74 quart dough in 43 seconds: on these points being joined by a line, it cut the 60 seconds line at very nearly midway between the 72 and the 74 quart lines, therefore the water-absorbing capacity was taken as being 73 quarts. In this way, the absorptive power of various flours for intermediate points between two readings was arrived at. An inspection of Fig. 79 shows that the upper portions of these lines, graphically representing absorbing capacity, are very nearly parallel to each other. The authors find if the first test made gives a viscometer reading between 45 and 90, that the water absorption may be deduced with sufficient correctness for most purposes in the following manner:—On a page, properly ruled both ways, set out two or three lines similar to those in Fig. 79 representing the water-absorbing power of different flours. Then, supposing a flour under examination has run through the viscometer in 87 seconds, with 68 quarts of water, make a mark at that point, and draw from it a line across the 60 seconds line, and parallel to the lines of other flours previously set out. Reckon the water absorption from the point where it cuts the 60 seconds line. Such a flour would probably absorb about 69.5 quarts of water. Judging from a number of flours that have been tested in this manner, the single test gives results that very seldom are more than 0.5 quart off from those obtained by doughing the flour with two different quantities of water.

Examples of a few detailed viscometer tests are given in the table on this page. The heavier figures are the calculated quarts per sack for 60 seconds.

Results of Viscometer Tests on Flours.

No.	Names and Description of Flours.
1.	Patent Flour, from American Hard Fyfe Wheat.
2.	Bakers' Flour, from American Hard Fyfe Wheat.
3.	Hungarian Flour, First Patent.
4.	English Wheat Flour.

TIME ALLOWED TO REMAIN IN DOUGH—ONE HOUR.

No.	Quarts per Sack.	Seconds.	No.	Quarts per Sack.	Seconds.
1	66	215	2	66	223
	68	193		68	200
	70	74		70	107
	71	**60**		72	86
	72	52		**73**	**60**
	74	44		74	43
	76	24		76	29
	78	10		78	16
	—	—		80	12
3	74	255	4	58	183
	76	170		60	120
	78	**60**		62	82
	80	38		**63**	**60**
	82	25		64	27
	84	18		66	19
	86	10		—	—

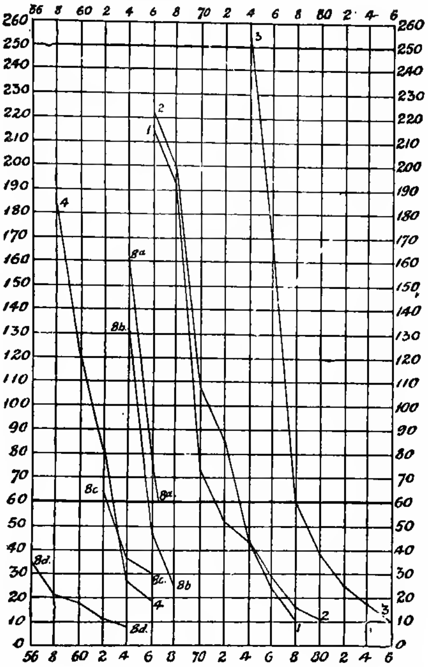


FIG. 79.—Diagram of Water-Absorption Results.

638. Colour.—This is probably at the same time one of the most difficult and most important tests to be made on flour. The great difficulty is that the colour of the flour itself is not necessarily a criterion of that of the bread produced. For example, some lower grade winter wheat flours look very white and even better coloured than harder spring wheat flours, whereas the bread made therefrom is exceedingly dark and ill-coloured. Further, the colour of the bread is dependent not only on that of the flour, but on the mode of working, and other factors which vary in themselves.

Unless tests are made for no other purpose than the comparison of flours placed side by side, it is absolutely necessary to have some means of measuring and registering colour. The most familiar, and on the whole the most successful, instrument for this purpose is that known as Lovibond's Tintometer or colour-measurer. As this appliance has been extensively employed in the following investigations, a description of it at this stage is necessary.

639. Lovibond's Tintometer.—The instrument itself is an optical device, Fig. 80, by means of which a sample of flour, bread, or other body may be viewed side by side with a prepared surface of the purest white obtainable. With the instrument is furnished a set of transparent standard tinted glasses. These are numbered from 0.01 upwards to 5.0, or higher if wished, so that any degree of depth of tint may be built up from these glasses, proceeding upwards by intervals of 0.01 at a time. For flour-testing purposes three series of such tinted glasses are employed. One of these is a Yellow, the second a Red, and a third Blue.

The base, A, carries a stand, A^1, which is supported in an oblique position by the strut, A^3. On this stand is placed the optical instrument itself, B. This consists of a tube, blackened on the inside, and having

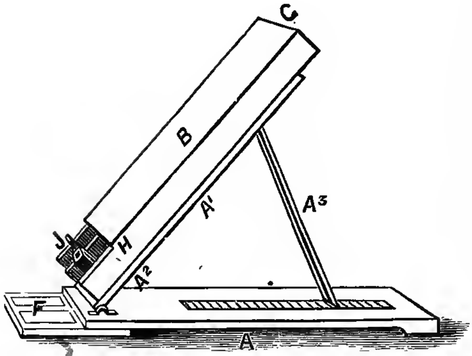


Fig. 80.—Lovibond's Tintometer.

apertures on the upper end, G, through which one looks in using the instrument. These openings are three in number, the outer ones being intended for use with both the eyes simultaneously, while that in the middle is for the purpose of one-eye examination. At the lower end of the tube, H, provision is made for the reception of two small cells, fitted with slits into which the standard glasses, J, are to be inserted. At F the coloured slabs under examination are placed for purposes of measurement.

The spongy texture of bread gives it a mottled appearance when viewed through this instrument, and so a special device is necessary by which the sponginess may be transformed into an even and uniform tint. This is shown in Fig. 81, which is a plan of the tintometer arranged for this purpose. K M is a flat stand, on which the tintometer, B, is fixed. At L L, between the cells for standard glasses, and H, are placed two lenses such as those employed for spectacles. At W the standard white comparing surface is arranged, and the slice of bread under examination is fixed at Y. On looking through the eye-pieces at G, the lenses throw both the white surface, W, and the bread, Y, out of focus, so that they appear as even coloured, structureless surfaces.

To use the tintometer, the standard white comparing surface must first be prepared. Fill one of the little trays supplied with the instrument with some specially prepared plaster of Paris, also supplied: press down with a piece of clean glass until a smooth uniform surface is obtained: if for bread, fill the cavity in the stand at W in the same way.

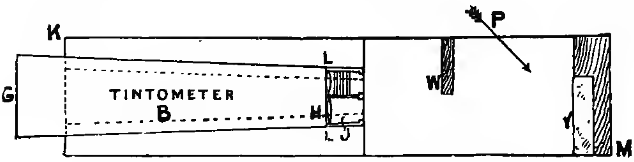


Fig. 81.—Tintometer Fitted for Use with Bread.

When using the first arrangement of the instrument, stand it in a convenient position facing a window looking toward the north, and, if possible, so that the light is from a white, cloudy sky, rather than when the sky is perfectly blue. In this latter case it is well to place a piece of white paper or white opal glass between the light and the surfaces being examined. On the one side of the field, F, place the tray of white, and the flour on the other. On looking down through the tintometer the flour will look much the darker. In the cell over the white surface put in some of the standard colour glasses already referred to—say, for example, 1.0 Y. (yellow) and 0.50 R. (red). The white light from the prepared surface passes up to the eye through these, and gives that surface an apparent yellowish red tint. Note whether the tint as a whole is lighter or darker than the flour, also whether too red or too yellow. If too dark and too red, remove the red glass and substitute a lighter one, and again compare. If too light and too red, add a little more yellow, leaving the red undisturbed. Very quickly it is possible to get the tint matched approximately: it is in getting an exact match that the difficulty occurs. It is well to try one or two modifications of the standard glasses, and see which comes the nearest. If the eye is uncertain, it is often an assistance to place a dark glass, say 5.0 Y., in front of the eye-piece, and look through the middle aperture at both the flours; they appear much darker. but minute shades of colour are thus more readily distinguished. Having got the tint which so closely as possible matches the flour, a register should be made of the numbers of the glasses composing it.

The bread form of the instrument should be arranged horizontally on a stand, so that it is at a comfortable height for the eyes of the observer when sitting, and so that the light comes from a window, over the shoulder, as shown by the arrow, P, Fig. 81. (If necessary, the instrument may of course be arranged for the light to fall from the right instead of the left.) Care must be taken that neither the surface, W, nor that of the bread has the shadow cast on it of any part of the apparatus. The use of the standard glasses in measuring is the same as before.

It is scarcely necessary to say that colour judgments are difficult, and to point out that different persons' eyes appreciate colours differently. One difficulty with the tintometer is, the comparison is being made between an opaque coloured surface in the case of the flour, and a tint imparted to a beam of light in the case of the test-surface—there is a difference in quality which makes comparison difficult. A desideratum is some form of permanent, graduated, tinted surface which can be compared with the flour.

The great value of the tintometer is for from time to time permanently measuring and checking the colour of standard flour samples: this is well worth any trouble taken in so doing. The standards being thus kept verified, it will be sufficient for ordinary purposes to check and compare flours side by side with the standards.

640. Colour Investigations.—In obtaining the readings made in connection with the following research, the judgment of four persons was, in many instances, utilised, while every reading was checked by at least two persons, and always, where the slightest doubt was felt, by three.

Among methods of judging the colour of flour the most obvious is that of testing the flour itself in the normal dry condition. To this there is the objection that the colour of dry flour depends not merely on the nature of the wheat and the flour constituents, but also on the comparative coarseness or fineness of the particles of the flour. Further, on exposure to air flour very quickly bleaches, although this of course does not effect the validity of a test made on a sample taken from bulk. The bleaching of flour is commonly ascribed to light, but this is not essential, for in the following experiment the samples were kept during the interval between readings in a dark cupboard. The following three dry samples gave tintometer readings as under, being simply pressed into smooth slabs and examined:—

	Immediate.			After standing one Day.	
	Yellow.	Red.		Yellow.	Red.
American Spring Bakers ..	0.27	0.06	..	0.25	0.04
Ditto, another sample ..	0.34	0.11	..	0.30	0.09
American Winter Bakers ..	0.20	0.02	..	0.11	0.02

Pêkar's Test.—A second and well-known method of testing colour is to dip the compressed slabs into water, so as to wet the surface, then allow the same to dry off, and read or compare the colours. The tint is in this instance darkened considerably as a result of the action of oxydase in the presence of air, coloured oxidative products being formed. In this case, again, the degree of granulation of the flour affects the depth of colour—a coarse flour absorbs more water, and becomes darker through taking longer to dry, while the surface has more or less "grain" as a result of roughness of the surface before wetting.

A third method consists of making the flour into dough, working it until perfectly smooth, and then examining and comparing. One objection to this method is that the colour of the dough darkens rapidly on the outside, and hence, if an attempt be made to read off the colour, or even compare a series of three or more at a time, a new dough surface darkens visibly while the comparison is being made. To obviate this, the pellet of dough may be placed on a sheet of *colourless* glass, and the colour of the dough observed *through* the glass—in this way the colour of the dough proper is seen as distinct from that of the outer skin. It is no uncommon occurrence to take two flours from the same variety of wheat, the one very fine and the other granular, and compare them either dry or wetted in compressed slabs. The granular flour under both tests looks the darker, but on working them into dough, as just described, the coarser flour often produces the more "bloomy" dough; bakers will at once form their own judgment as to which of the two will under similar conditions make the best loaf. Also, of course, the outer skin of the same samples may be compared and read if necessary.

Investigation shows that the colour of dough is influenced by its degree of stiffness. Thus, a spring bakers' flour was made into dough with different quantities of water, and the following readings taken at the expiration of one hour. At the end of thirteen hours, in which the doughs were kept in a water-saturated atmosphere, the colour of the outer skins was also read:—

	Colour of Dough.			Colour of Skin.		
	Yellow.	Red.	Blue.	Yellow.	Red.	Blue.
1. Doughed with 50% of water	1.50	0.68	0.08	3.55	2.10	0.86
2. Doughed with 55% of water	1.42	0.63	—	3.75	2.10	0.56
3. Doughed with 60% of water	1.19	0.54	—	3.15	1.90	0.48

The colour both of dough and skin is darker in the tighter doughs; also this relation of colour holds good for some time, for at the end of eighteen hours the *order* of colour of the dough was the same as at the end of one hour.

In order to eliminate so far as possible the differences due to variations in tightness of doughs, the whole of the flours were in the subsequent tests treated with the quantity of water sufficient to make doughs of uniform stiffness. For this purpose each flour was tested by the viscometer in the manner previously described. The next step was to investigate the influence of the length of time the dough had stood on the depth of colour; this, be it remembered, always being read through colourless glass. The following results were obtained:—

Time.	Winter American Patent.		Winter American Bakers.		Spring American Patent.		Spring American Bakers.	
	Y.	R.	Y.	R.	Y.	R.	Y.	R.
1 hour after mixing	0.92	0.29	1.37	0.94	1.02	0.64	1.34	1.10
2 hours after mixing	1.02	0.36	1.49	0.97	1.09	0.64	1.49	1.00
3 hours after mixing	1.08	0.40	1.50	1.00	1.25	0.75	1.52	1.07
4 hours after mixing	1.10	0.43	1.51	1.00	1.20	0.65	1.47	0.97
22 hours after mixing	1.08	0.58	1.50	1.02	1.20	0.75	1.46	1.07

It may be well here to explain the precautions taken in order to get as exact readings as possible. First of all, every series of tests to be read were arranged in order of colour as apparent to the eye; then they were read in succession, commencing with the lightest. After matching No. 1, No. 2 was placed against its (No. 1's) standard tint glasses and seen to be darker, then measured. In all cases where there was any apparent discrepancy the reading received a checking by three persons. When making time measurements the following method was adopted:—First of all, at the expiration of the time, the colour glasses of the preceding reading were again placed in the instrument, thus taking, for example, the two hours' reading on the first flour just given, the one hour glasses, Y. 0.92; R. 0.29 were inserted, and the dough compared with them. It was definitely ascertained that a distinct darkening had occurred; its measurement then followed. Each reading was thus compared with that preceding throughout the whole series. It will be observed that a slight but steady darkening occurs throughout the whole series, the increasing red or foxy tint "saddening" the bloom of the yellow. Unless otherwise stated, future readings were made on doughs after standing one hour.

The authors have also adopted another method of preparing the flour for examination, which is really a modification of the Pékarised slab method. The testing Pfleiderer doughing machine is thoroughly cleaned by making a stiff dough in it, and thus removing anything that would injure the colour. A dough is made by taking 30 grams of flour and 15 grams of water, and then pinning it out into a thin sheet—say three-sixteenths of an inch thick—on a piece of glass. This is allowed to dry off in a dark place and then read just like the Pékar slab. It has the advantage of giving a smooth surface with all errors due to the "grain" of the flour eliminated; but has the disadvantage that the degree of darkening depends somewhat on the thickness of the sheet.

The next and final test is that made by baking the loaf and then observing the colour of the bread. It is scarcely necessary to point out to bakers that colour is influenced by the kind of yeast used and mode of working; but using the same yeast, it was thought well to register the effect produced by the mode of fermenting employed, and especially the time of fermentation. A spring American bakers' flour was first made into an off-hand dough in the following manner:—

10 lbs. flour,
5 lbs. water at 90° F.,
1½ oz. compressed yeast (Delft Pure), and
1¼ oz. salt,

were taken and made into dough at 5 p.m. The dough was then maintained at a temperature of 80-82° F. during the whole time of the experiment. At intervals a 2 lb. piece was taken, moulded, and baked. On the next morning the loaves were cut, the colour examined, and also the total acidity, reckoned as lactic acid, determined. On the second day also the colour was read, a freshly-cut surface being used for that purpose. The following table gives the results obtained. The first column gives the number of hours after setting the dough until the loaf was placed in the oven; the first day's colour readings follow in the second column, the next days in the third, and the acidities in the last.

TESTS ON BAKERS' FLOUR—OFF-HAND DOUGH.

No.	Hours.	First Day's Colour.			Second Day's Colour.			Acidity.
		Y.	R.	B.	Y.	R.	B.	per cent.
1	4	2.11	1.41	0.30	1.85	1.25	0.16	0.57
2	6	1.75	1.25	0.18	1.91	1.10	0.26	0.63
3	8	1.75	1.00	0.10	1.85	1.10	0.26	0.66
4	10	1.75	1.20	0.10	1.75	1.30	0.26	0.69
5	12	1.70	1.15	0.05	1.66	1.20	0.24	0.73
6	13½	1.70	1.20	0.30	1.75	1.40	0.30	0.79

Fermentation had not proceeded sufficiently far to properly raise the first loaf, which was somewhat close and heavy, and also dark in colour; but it should be borne in mind its texture could scarcely be in fairness compared with that of the other numbers of the series. The last showed signs, but only slight, of darkening—due doubtless to the commencement of those changes which accompany sourness. The loaves Nos. 2 to 5 do not vary greatly in colour, but there is a slight diminution of the depth of tint. Taken as a whole, this series darkened before the second day.

In another series of tests two doughs were worked with a flour ferment. The one was from a spring American patent flour; the second from a bakers' grade from the same wheat. The following quantities were in each case employed:—

¾ lb. flour 3 oz. compressed yeast 5 lbs. (2 quarts) water at 102° F.	Ferment.
9¼ lbs. flour	Dough.

The ferment was allowed to work 45 minutes from the time of being set; then the dough was made, and one loaf immediately taken. This was allowed to prove, and at once baked. Loaves were taken at intervals as shown in the following table, in which is also given the colour and acidity both on the first and second day after baking. It should be added that the first loaf was baked at about 9.15 p.m.

TESTS ON BAKERS' FLOUR—FLOUR FERMENT AND DOUGH.

(*Same sample as used in previous series.*)

No.	Hours.	First Day's Colour.			Acidity	Second Day's Colour.			Acidity
		Y.	R.	B.	per cent.	Y.	R.	B.	per cent.
1	Immediate	1.80	1.15	0.50	0.65	1.40	0.96	0.06	0.59
2	2 hours	1.65	1.20	0.40	0.73	1.48	1.00	0.04	0.71
3	4 “	1.65	1.30	0.40	0.72	1.42	1.00	0.04	0.90
4	6 “	1.90	1.80	0.60	1.05	1.60	1.40	0.05	1.12
5	7½ “	2.20	2.08	0.75	1.17	1.60	1.45	0.08	1.27
6	9½ “	2.22	2.15	0.75	1.10	1.65	1.40	0.08	1.34

REMARKS.

No. 1. Very close and heavy.
No. 2. Sweet, good loaf.
No. 3. Colour slightly worse, odour faulty.
No. 4. Decidedly sour, rapid darkening in colour commenced.
No. 5. These changes intensified.
No. 6. These changes still more marked.

The colour here distinctly fell off, with increase of acidity, a distinct difference being observed even between Nos. 2 and 3. The off-hand doughs were, as a series, whiter than those prepared with a ferment, but this is probably due to the excessive fermentation in the latter series, which was intentionally pushed to an extreme. Taken as a whole these loaves were distinctly less coloured on the second day.

The following are the results of the corresponding series of tests on patent flour:—

TESTS ON PATENT FLOUR.

No.	Hours.	First Day's Colour.			Acidity per cent.	Second Day's Colour.			Acidity per cent.
		Y.	R.	B.		Y.	R.	B.	
1	Immediate	1.45	0.70	—	0.29	1.40	0.72	—	0.32
2	2 hours	1.40	0.62	—	0.35	1.60	0.73	0.05	0.37
3	4 "	1.30	0.60	—	0.50	1.32	0.65	0.06	0.52
4	6 "	1.75	0.98	—	0.63	1.60	1.01	—	0.68
5	7½ "	1.70	1.01	—	0.70	1.40	0.90	—	0.73
6	9½ "	1.70	1.02	—	0.75	1.48	0.93	—	0.82

REMARKS.

No.	First Day.	Second Day.
1.	Close and heavy—Sweet	Sweet.
2.	Bright and good bloom—Sweet	Sweet.
3.	Greyer, very little different—Sweet. Both 2 and 3 good volume	Incipient sourness.
4.	Smaller, darker, slightly sour	Sour.
5.	Smaller, darker, sourer	Sour.
6.	Very small, dark, very sour	Very sour.

Again, with an increase of acidity, there is also a darkening of colour; and in the earlier numbers of the series also a darkening on the second day's reading as compared with the first. There is a property of bread colour to which attention has already been drawn by Abercromby, which property renders comparison difficult both to the eye and also the tintometer. That property is " a silky texture in the bread, which, by reflecting the light, gives an appearance of better colour." To this characteristic the authors venture to apply and appropriate the term "*sheen.*" The difficulty is that a loaf looks more "*sheeny*" in one position than another; not only may two observers, the one looking over the other's shoulder, get a different impression, but the sheen may be affected even by slightly turning or altering the position of the loaf. One reason why the patent flour breads suffer in colour on the second day is the loss of brilliance or sheen.

641. Effect of Age on Flours.—The experiments set forth in the table on page 496 were made in order to determine the effect of age on American flours. All the tests were made at various times on 14-lb. samples, stocked meantime in close textured canvas bags. The first tests were made on the arrival of the flours in this country in October; the second series after the lapse of three months, in January; and the third after the expiration of another two months, in March. The colour on dry flour, wet gluten, and water absorption by viscometer were in each case determined.

With increase of age a slight, but only a slight, amount of bleaching is observed. In connexion with this, it will be of interest to note the difference in colour between a sample of flour by which purchase was made on Mark Lane, and the colour of bulk when delivered some weeks later. The seller alleged that the difference in colour between bulk sample and selling sample was due to bleaching of the latter in the interval between date of purchase and arrival of the flour.

	Colour of Sample.	Bulk.
Dry Flour	0.10 Y. + 0.01 R.	0.32 Y. + 0.90 R.
Pékarised Flour ..	1.32 Y. + 0.50 R.	2.20 Y. + 0.90 R.
Dough, through glass ..	1.10 Y. + 0.60 R.	1.50 Y. + 0.90 R.

Comparing the above results with the amount of bleaching on authentic samples, comment is unnecessary.

The amount of gluten and also water-absorbing power by viscometer show generally signs of slight diminution.

EFFECT OF AGE ON FLOURS.

No. 1. Bakers' Flour from Duluth Wheat.
„ 2. Patent „ „
„ 3. Bakers' „ Manitoban Wheat.
„ 4. Patent „ „
„ 5. Bakers' „ Indiana Winter Wheat.
„ 6. Patent „ „ „
„ 7. Bakers' „ Ohio Winter Wheat.
„ 8. Patent „ „ „

Colour.		1.	2.	3.	4.	5.	6.	7.	8.
New	Y	0.30	0.21	0.27	0.22	0.20	0.07	0.18	0.06
	R	0.07	0.04	0.06	0.06	0.03	0.02	0.03	0.02
Three months old	Y	0.29	0.22	0.27	0.22	0.16	0.06	0.16	0.08
	R	0.07	0.02	0.06	0.04	0.03	0.02	0.02	0.01
Five months old	Y	0.28	0.21	0.26	0.22	0.16	0.06	0.14	0.06
	R	0.07	0.02	0.04	0.04	0.03	0.02	0.02	0.01
Wet Gluten.									
New	..	44.0	42.0	44.5	39.0	37.0	28.9	33.7	31.8
Three months old	..	43.7	41.7	37.4	36.2	30.6	29.1	33.3	30.2
Five months old	..	43.2	41.2	35.7	35.0	30.1	28.9	32.7	30.3
Water Absorption.									
New	..	69.5	68.0	66.0	63.5	59.0	53.0	56.0	57.5
Three months old	..	68.5	67.0	67.5	66.0	60.0	55.0	56.0	55.5
Five months old	..	66.0	62.0	66.0	63.0	55.0	51.0	56.0	55.0

642. Baking Tests.—In comparing the relative value of baking tests with those made by analytic methods, it should be borne in mind that the latter are obtained by processes in which all disturbing influences are so far as possible eliminated, whereas in baking tests the quality of the yeast, temperature of working, etc., are all disturbing elements. As seen by preceding results quoted, the colour and other characteristics of the bread are affected by differences in the mode of performing baking tests. In baking tests, again, the individuality of the baker must largely come into play, as he will naturally treat the flour in the manner most nearly comparable with his own general mode of working. As no two bakers work exactly alike, one set of results may not quite agree with those obtained by another baker working in a somewhat different manner, and with not altogether the same objects in view.

643. Baking Tests, Thatcher.—Thatcher has recently summarised the various methods proposed for the testing of flour, and describes those recommended and adopted by him in the laboratory of The Washington Agricultural Experiment Station, U.S.A. The following is a description of his mode of making baking tests:—

Quantities taken.

Flour	340 grams.
Yeast	10 „
Sugar	12 „
Salt	5 „
Water	A Sufficiency.

These were then kneaded in a special machine for twenty minutes, so arranged as to maintain the dough at a temperature of 90° F. for that time. The dough was then transferred to a greased tin, and placed in a proving box or cupboard maintained at 90°. Here it was allowed to rise until it just touched a tin strip laid across the top of the tin. The tin was then transferred to an electric oven heated to 400° F., and baked for forty minutes. The bread was allowed to cool for thirty minutes, after which the weight and volume were determined. The latter was effected by measuring in a cylindrical box with seeds. Thatcher concludes that it is impossible to form final conclusions as to the baking quality of a flour from the results of a chemical analysis alone. Further, he is of opinion that no single test which was tried is capable of giving conclusive evidence as to the baking quality of flour. Any such processes as have yet been suggested must be supplemented by a baking test if final and accurate conclusions are to be reached. (*Jour. Amer. Chem. Soc.*, 1907, 910.)

644. **Baking Tests, Method Employed by the Authors.**—The quantity of flour taken for a baking test may vary according to the custom and requirements in any particular district. Usually, however, it is desirable to keep the quantity as low as practicable, so that a test may be made on a small sample: at the same time the loaf should be of a fair size, so as to compare as well as possible with the bread made for commercial purposes. The authors employ the following quantities, which answer well for general purposes.

Quantities.—Flour .. .. 560 grams = 19.71 oz.
Water as per Viscometric Absorption, or otherwise determined.
Salt .. .. .. 6 grams
Compressed Yeast .. 10 grams

The metric system of weights is adopted because of its greater simplicity and the readiness with which exact weights can be determined. The quantity, 560 grams, is 2 grams for every lb. of flour in the sack, so that one half the weight of any constituent or product is without any further calculations the weight in lbs. that would be obtained proportionately by treatment of the sack of flour.

The resultant loaf of bread usually weighs from 1½ lbs. to 1¾ lbs., and although less than the weight of a 2-lb. loaf, is yet sufficiently near to enable a comparison to be instituted.

Bearing in mind that the proportions of water used vary very considerably in different parts of the United Kingdom, the authors, for general tests, have adopted the plan of making where possible three separate bakings on each flour, distinguished respectively as *a, b, c*. For *b*, what is believed to be the best quantity of water is employed. This may be determined by a water-absorption test, controlled by the viscometer or otherwise. It will be remembered that that instrument gives results in quarts per sack; and as a quart weighs 2½ lbs., the number of quarts × 5 gives the weight in grams or volume in cubic centimetres of water that must be taken to the 560 grams of flour. For *a*, 20 grams (equivalent to 4 quarts) less water is taken than in *b*: while in *c*, 20 grams more water is added than used in *b*. The three tests, therefore, represent quantities of water with differences of a gallon to the sack between each, and cover all variations in quantities for ordinary bread-making. Another advantage of testing in this manner is that it provides for those flours which fall off very much during fermentation. In other words, some flours will not in reality take as much water as might be judged from the tightness of the dough when first made. Conversely, other flours fall off less than the normal in fermentation, and evidently require more water than is indicated by the character of the dough at the moment of preparation. Where one test only is made, a very frequent comment is—this flour would have been better with a quart or two quarts more [or less] water. If a series of tests is made, one of them is likely to closely agree with the quantity of water best suited to the flour throughout its whole fermentation. If thought preferable the difference between each test may be taken at some other figure than the gallon.

Mode of Fermentation.—First weigh out the flour, and put it in a pan of sufficient size (for which purpose an ordinary white pudding-basin, 8 or 9 inches internal diameter, answers well). Next take the temperature of the flour, and if anything below 70° F., carefully warm it until that temperature is reached. A convenient method in the testing laboratory of doing this is to stand the basin containing the flour in hot water, and stir the flour continually with a spatula until sufficiently warm. A "ferment" is next made with the whole of the water to be used. This water may be either measured or weighed; if the former course be adopted, the measures should be specially graduated to deliver grams of water at 100° F. It has been found convenient to have the ferment, when set, at 90° F.; the initial temperature of the water should be so adjusted by experiment as to give this temperature at the finish; usually about 10° is lost in this operation, and therefore the water may be taken at 100° F. Make a hole in the middle of the flour (bay), and having the water in a measure, break down the previously weighed yeast into the water, and pour the whole into the bay. Work carefully a little of the flour into the liquor so as to form a ferment of the consistency of a thin batter: this ferment, as above stated, should have a temperature of 90° F. For the fermentation there should, when practicable, be provided a proving cupboard, so arranged as to just take, on a series of shelves, a number of these basins, all of which must be labelled and marked. By some convenient means the temperature of this cupboard should be maintained at about 85° F.; this may be done either by the injection of a jet of steam, or the well-known plan of a small atmospheric burner at the bottom of the cupboard, with a vessel of water over it. The temperature of this cupboard should be under control, and must be kept uniformly at the desired degree.

Cover the basin containing the ferment with a light linen cloth, and place it in the proving cupboard for one hour; at the end of that time the ferment will be "ready," and should have nicely dropped. Add the finely-powdered salt, and stir in the flour and salt into the ferment with a bone spatula. Knead thoroughly either by hand, or preferably in one of Werner and Pfleiderer's small doughing machines, taking care that no loss occurs during the operation, and that the dough is made perfectly smooth. Return to the proving cupboard, and after one hour well "knock down" the dough: place again in the cupboard for half an hour, and then weigh the dough accurately. The bread may be baked in a tin, or for most purposes, preferably, as a cottage loaf. Mould, and allow to stand for a few minutes if necessary. Moulding should, if possible, be done without dusting flour; when any is used, a quantity should be weighed, and that remaining after the moulding of each loaf again weighed, and note made of the quantity used. This should not exceed 2 grams per loaf. Bake in an oven, the temperature and behaviour of which is known, and, if possible, together with loaves of a familiar flour, so as to be able to judge the comparative tendency of the flour to take the fire. When baked, allow the bread to stand twelve hours—say over night—and then weigh. Notice whether the bread happens to be burned at the bottom, and if so make a note, as the weight will thereby be affected.

Note the character of the loaf, compared with a standard or known sample; whether of good volume, bold and well shaped, twisted or flat; also the colour of the outer crust, and likewise in the partings between the top and bottom of the cottage.

If wished, the volume of the loaf may be determined by means of a cylindrical measure sufficiently large to hold it completely. The loaf is placed in this, and rape seed or other small seed added to fill the measure, the upper surface of which is then "struck." The quantity of seed used is then measured, preferably in a vessel graduated in cubic centimeters, and also the quantity of seed similarly required to fill the measure without the loaf. The difference gives the volume of the loaf.

Compare the appearance of the three loaves side by side, and decide which represents the bread from the best size or stiffness of dough. Note also whether there is a great difference between each, as some flours stand an excess of water over the normal far better than others.

Next cut the loaf in the direction of greatest outline, and observe the colour, texture, pile, and sheen of crumb; also moistness, odour, and flavour of crumb. (It should be borne in mind that the flavour of a small baking test is not an absolute criterion of that of bread regularly made in full-sized batches.) The colour may be measured and registered when thought desirable by means of the tintometer modified by the addition of de-focussing lenses.

If wished, a system of giving marks for colour, texture, flavour and other characteristics may be adopted. In fixing these a maximum and minimum should be decided on, and then the loaf being tested should have its intermediate position indicated as accurately as possible by the number of marks given.

If it is desired to keep a permanent record of its size, the cut loaf may be placed on a sheet of paper, and marked round with a pencil. This may be done on a leaf of a note-book, and the other data placed on the opposite page.

The following are given as an example of how baking tests may be entered in the note-book, together with deductions made therefrom:—

Description of Flour—High-Class English Patent.

Water absorption by Viscometer—60 quarts per sack.

	a	*b*	*c*
Flour in grams	560	560	560
Water "	280	300	320
Yeast "	10	10	10
Salt "	6	6	6
Unfermented Dough in grams	856	876	896
" " lbs. per sack	428	438	448
Fermented Dough in grams	827	850	860
" " lbs. per sack	413.5	425	430
Fermented Dough calculated into loaves of 4 lbs. 6 oz. per sack	94.5	97.1	98.3
Weight of Bread, 12 hours old, in grams	707	737	760
Weight of Bread, 12 hours old, in lbs. per sack	353.5	368.5	380
Loaves of 4 lbs. each per sack	88.4	92.1	95.0
Colour of bread by Tintometer—Yellow	1.35	1.35	1.35
" " " Red	0.70	0.75	0.75

In the above results the mode of determining lbs. per sack is self-evident: quantities in grams are simply divided by 2. Calculated loaves per sack from dough are obtained from lbs. per sack by reducing to ounces and dividing by 70 (ounces = 4 lbs. 6 oz.). The readiest way of performing this calculation is to multiply in grams by 8 and divide by 70, thus:

$$\frac{827 \times 8}{70} = 94.5 \text{ loaves per sack.}$$

The results obtained as yield in bread by calculating at 4 lbs. 6 oz. on the dough are more trustworthy than those by direct weighing of the bread itself, as single sample loaves will vary more in weight from the normal than does a full batch calculated on the weight of dough.

645. Special Apparatus for Baking Tests.—When baking tests are being conducted on a large scale, certain special appliances enable results to be obtained not only with greater speed, but with more exactitude.

For water measuring purposes it is very convenient to employ a large burette and reservoir similar in character to that figured No. 77 for making viscometric determinations. The burette should have a capacity of 400 c.c., and should be provided with a large way tap. The reservoir should be open at the top, but provided with a cover: a number of tests having to be made, sufficient water should be in one operation adjusted to the right temperature, and used for the whole series that are started off together.

Where it is possible to bake sample loaves with a batch of ordinary bread, that forms one of the best modes of procedure. It has the great advantage for crusty bread that a better shaped loaf is produced than when single loaves, or some two or three only, are baked in a small oven. For laboratory work, however, a special oven is usually necessary. For this purpose the authors have for some time used a specially constructed electrically-heated oven. The top and bottom heats are under separate control and very satisfactory results are obtained, the bread being well and evenly baked.

646. Alternative Scheme for Baking Tests.—For the convenience of those who prefer to work entirely with English weights the following directions for making a baking test are given: the quantity of flour used, 3 lbs., produces from 4 lbs. to 4½ lbs. of bread. This may be baked either in tin or cottage loaves.

First determine the water-absorbing capacity of the flour either with burette alone, or in conjunction with the viscometer. Make a dough either of full viscometric strength, or as much tighter as may be necessary to suit the requirements of the district. This can readily be done by deciding once for all on a constant deduction from the water-absorbing capacity according to the sixty-seconds standard.

With 7 lbs. of flour, each ounce of water used is equivalent to one quart per sack. For tests on 3 lbs. of flour the water in ounces, equivalent to quarts per sack, is obtained by multiplying by 3/7; thus 50 quarts per sack equal 21.4 ounces per 3 lbs. of flour. The following table gives the proportionate quantity of water for 3 lbs. of flour, from 50 to 81 quarts per sack:—

50 quarts = 21.4 ounces.
51 ,, 21.8 ,,
52 ,, 22.3 ,,
53 ,, 22.7 ,,
54 ,, 23.1 ,,
55 ,, 23.5 ,,
56 ,, 24.0 ,,
57 ,, 24.4 ,,
58 ,, 24.8 ,,
59 ,, 25.3 ,,
60 ,, 25.7 ,,
61 ,, 26.1 ,,
62 ,, 26.6 ,,
63 ,, 27.0 ,,
64 ,, 27.4 ,,
65 ,, 27.8 ,,
66 quarts = 28.3 ounces.
67 ,, 28.7 ,,
68 ,, 29.1 ,,
69 ,, 29.6 ,,
70 ,, 30.0 ,,
71 ,, 30.4 ,,
72 ,, 30.8 ,,
73 ,, 31.3 ,,
74 ,, 31.7 ,,
75 ,, 32.1 ,,
76 ,, 32.6 ,,
77 ,, 33.0 ,,
78 ,, 33.4 ,,
79 ,, 33.8 ,,
80 ,, 34.3 ,,
81 ,, 34.7 ,,

Quantities.—Flour 3 lbs., water as per table, salt ½ oz., yeast ¾ oz. Weigh all ingredients as accurately as possible.

First, weigh out the flour, and put it in a pan of sufficient size; take out about an ounce of the flour, and put it aside in a small cup. Counterpoise a jug on the balance, and weigh out the requisite quantity of water, warmed to a temperature of about 85° F. Weigh the salt and rub it with the hands into the flour; add the weighed yeast to the water and mix it thoroughly, taking care to break down any lumps with the fingers. Make a hole in the middle of the flour, and pour in the yeast and water; stir it sufficiently to work enough of the flour into the water to form a thin sponge: cover this over by drawing up a little of the flour from the sides. Let this stand for an hour in a warm place, covered over with flannel. Then knead the whole into a dough. Clean all fragments of dough from the hands, and rinse them in a little of the reserved flour; let the rinsings go into the dough. Let the dough ferment for from 3 to 4 hours. In the meantime, grease and weigh a 4-lb baking tin. Dust a perfectly clean kneading-board with a little of the reserved flour, and turn out the dough from the basin, cleaning it as thoroughly as possible with the fingers. Mould the dough into a loaf, using up in so doing the remainder of the reserved flour. Transfer the loaf to the tin, taking care that as little as possible is lost. Notice to what extent the dough has become slacker during fermentation, also whether elastic or possessing very little tenacity. Let the dough prove in the tin for about an hour, then weigh. Next bake for an hour, or an hour and ten minutes, according to the heat of the oven. Remove the loaf from the tin and allow it to cool; in an hour weigh the loaf. Note the colour of the crust, odour of the bread when warm, etc. Next, with a sharp knife, cut the loaf across its highest part; note the colour, texture, flavour, and degree of moisture of the interior. Keep for a day or two and repeat these observations.

If it is desired to keep a permanent record of the test, a good plan is to place the cut loaf on a sheet of paper, and mark its size round with a pencil. A large-sized exercise book, without lines, answers this purpose very well. The other data may be so arranged as to come inside the outline of the loaf.

Another convenient method of making a baking test is by taking a definite quantity of water, and adding flour to the same until a dough of the right consistency is obtained. The dough is then weighed: the weight of water, yeast, and salt used always being a constant, that of flour is simply obtained by difference from the weight of the dough. A table is easily calculated giving equivalent yields per sack from weight of dough in each case.

General Interpretation of Results.—This it is hoped has been rendered sufficiently clear by the explanatory remarks on the different constituents and properties of flour, by which the description of each is accompanied. It must be remembered that baking tests on small quantities of flour are only to be viewed as comparative; because, as in all operations conducted on a commercial scale, the results obtained in practice fall below those yielded by direct tests on small amounts of material. Consequently, it must not be assumed, because 7 lbs. of flour yield a certain weight of bread when baked with every precaution taken against loss, that the sack of 280 lbs. will yield 40 times that weight of bread. Still it is well, from time to time, to gauge the theoretical yield by a small test, as information is thus obtained as to how closely the practical and theoretical yields agree with each other. By keeping a closer watch on this point, many bakers could lessen considerably various sources of loss which now occur, and are almost unnoticed. In case it is wished to make the baking test a means of estimating how much the actual working yield of flours is, a careful comparison must first be made between the results obtained by a small baking test, and one on a sack of the same flour. Divide the yield of bread from the sack by that from the quantity used for small test: then the quotient may be used as a multiplier in order to convert the small test yield into working yield per sack. Thus, suppose that this quotient is, in the case of a 7 lb. test, 39: then whatever weight of bread is yielded by a 7 lb. baking test, that quantity multiplied by 39 gives the approximate yield per sack. But the figures thus obtained must not be relied on too absolutely, as disturbing elements occur when working on the large scale which are avoided when making experimental tests. It is on the whole safer to view experimental tests as affording information on the comparative merits of flours, rather than as an indication of absolute yield by the flours when baked in large quantities.

CHAPTER XXII.

DETERMINATION OF MINERAL AND FATTY MATTERS AND HEAT OF COMBUSTION OF WHEATS AND FLOURS.

647. Determination of Ash.—To determine ash, weigh a small platinum or silica dish, and then add five grams of the flour or meal; place the dish on a pipeclay triangle resting on the ring of a retort or tripod stand, and burn the flour by gently heating with the bunsen. The volatile matter burns off readily, and leaves behind a cake of ash mixed with carbon; the heat must be continued until the carbon has disappeared, leaving only the ash, which must be white, or of a greyish tint. The heat must not be raised too high; the burning off of the carbon may be facilitated by occasionally stirring it with a fine platinum wire. Take care that when this is done none of the ash is lost by being removed with the wire. When the burning is complete allow the dish to cool in the desiccator, and weigh. When wheat or flour is burned in this manner, the resultant ash is generally infusible at the temperature employed. The more than usually ready fusibility of the ash is an indication of the addition to flour of some readily fusible salt. With a very fusible ash there is a difficulty in burning the flour or other substance completely, since the fused salts enclose particles of carbon and protect them from the oxygen of the air. In the case of such an ash, the carbonaceous mass may be extracted with successive quantities of hot distilled water. This may be done either in the dish, or the partly burnt ash may be transferred to a clean mortar and first reduced to a fine powder and then treated with the water. The solution is filtered, and the carbon returned to the platinum dish and carefully dried, after which it is again heated with the bunsen. The carbon will then usually burn off freely. The filtrate is next evaporated to dryness in the same dish and heated. A carbon-free ash is thus obtained. It sometimes happens that an ash encloses just a few particles of carbon somewhat obstinately. A small quantity of hot water to dissolve soluble matter should then be added, and the solution distributed by giving a circular movement to the dish. The contents are evaporated to dryness and again ignited. This very simple treatment will frequently secure the elimination of the last traces of carbon.

Instead of heating over a bunsen flame, a muffle may be employed with advantage in ash determinations. This piece of apparatus consists of what is really a very small oven made of fire-clay and contained in a muffle-furnace. By means of a powerful gas burner the whole muffle is heated to dull redness, and in a current of air, flour and similar substances burn readily to a carbon-free ash. If wished, the muffle may be arranged for heating by means of a specially applied electric current.

648. Ash Estimations, Snyder.—Snyder attaches great importance to the determinations of ash in flour. He finds that the percentage amount of ash in different wheat crops varies but little from year to year. The ash determination is of value in establishing the grade of a flour. The more completely the bran, shorts, and germ particles are removed, the smaller is the ash content. There is a definite relationship between the ash content and the grade of the flour. The ash is more constant in amount and composition than any other class of compounds found in wheat, consequently the ash content of the different grades of flour is quite uniform. The patent grades of flour almost invariably contain less than 0.50 per cent. ash. The range in ash content of the different grades of spring wheat flour is approximately as follows:—

	Per cent. Ash.
First Patent	0.35 to 0.40
Second Patent	0.40 to 0.48
Straight Grade	0.48 to 0.55
First Clear	0.60 to 0.90
Second Clear	0.90 to 1.80

Flour made from fully matured wheat has the minimum ash content, because high maturity is usually accompanied by a low ash. The ash determination cannot be used to establish the comparative value of two samples of flour belonging to the same grade; for example, if two samples of flour contain respectively 0.36 and 0.40 per cent. ash, the one with the lower per cent. is not necessarily the better flour. If, however, two samples of flour contain respectively 0.42 and 0.55 per cent. ash, the former is a patent grade and the latter a straight grade flour. In grading Hungarian flours, the ash determination has been used successfully by Virodi. When making comparisons, however, too strict an application of the results is not admissible, particularly when the ash determinations are made in different laboratories and by different analysts, as the results then are not always strictly comparable. When the ash determinations are made under similar conditions, the results are of much value in determining the grade of a flour. (*Bull. No.* 85, *Agric. Expt. Station, Univ. of Minnesota,* 1904.)

Should the ash of any flour be higher than would be expected from comparison with that of a flour of corresponding colour of the same character, the addition of mineral substances may be expected. An analysis of the ash would then show whether or not its composition was normal for flour, or whether some foreign ingredient was present.

649. Determination of Phosphoric Acid, P_2O_5, and Potash, K_2O, in Ash.—When it is desired to estimate both these constituents, take 50 grams of flour, and heat in a platinum dish until the whole of the volatile matter, and most of the carbon, is burned off, then moisten with concentrated hydrochloric acid without removal from the dish. Evaporate to complete dryness, first over the water-bath and then by gentle ignition with the bunsen. This operation renders the silica present insoluble; add warm dilute nitric acid to the ash, and filter from silica and any unburnt carbon: wash the filtrate with the warm acid. The solution thus obtained contains the phosphoric acid, together with the iron, lime, and other bases. This solution must now be made up to a definite volume in a measuring flask, say 250 c.c.; 100 c.c. may then be taken for the phosphoric acid estimation, and a similar quantity for the determination of potassium.

650. Phosphoric Acid Estimation.—For the purposes of this estimation two special reagents are required, known respectively as "Molybdic solution" and "Magnesia mixture."

651. Molybdic Solution.—Dissolve 150 grams of ammonium molybdate, Am_2MoO_4, in a litre of water. Make up a litre of nitric acid of about 1.20 specific gravity; this may be obtained sufficiently near by taking 500 c.c. of commercially pure acid of 1.4 sp. gr., and adding thereto an equal quantity of water. Pour the molybdate solution into the nitric acid (the mixture must not be reversed). The solution thus obtained must be kept in the dark.

652. Magnesia Mixture.—Dissolve 110 grams of magnesium chloride, $MgCl_2$, and 140 grams of ammonium chloride, AmCl, in 1300 c.c. of water; dilute this mixture down to two litres with the strongest liquid ammonia.

653. Mode of Analysis.—By means of a pipette draw off 100 c.c. of the solution of ash (made up as before directed), and pour it into an evaporating basin. Concentrate by evaporation over a water-bath until the volume is reduced to about 30-40 c.c., transfer to a beaker, carefully rinsing the basin with distilled water in small quantity. Add to the solution thus obtained about 100 c.c. of molybdic solution, and allow the mixture to stand for at least three hours at a temperature of about 50° C. The top of the hot-water oven is a very good place on which to put the beakers during this time; the solution may, if it happens to be convenient, be allowed to stand a longer time—all night, for instance—without injury. A bright yellow precipitate forms, which contains all the phosphoric acid, together with molybdic acid; but as the composition of the precipitate is not constant, it cannot be weighed for the purpose of determining phosphoric acid. The bases remain in the filtrate. Bring the precipitate on to a small filter, and there wash with a solution of ammonium nitrate until the washings no longer redden litmus paper. Test the first portion of the filtrate by adding a drop of sodium phosphate solution to a very small quantity, and warm gently—a yellow precipitate shows that the molybdate has been added in excess. Should there be no precipitate, some more molybdic solution must be added to the main portion of the solution, which must then be allowed to stand as before in a warm place. Next dissolve the precipitate in the least possible quantity of warm ammonia solution (one part strong ammonia to three parts of water). This operation is best performed by pouring the warm ammonia on to the filter. When this has passed through, if any more of the precipitate remain on the filter, return the filtrate to the filter, and repeat this operation until the whole of the precipitate is dissolved. While pouring the filtrate back on the filter, place another beaker in order to catch any drops of the filtrate. Wash out one of the beakers, and also the filter, with the warm ammonia solution. This solution contains the phosphoric acid as ammonium phosphate; to it add about 10 c.c. of magnesia mixture, and one-third of the total volume of strong ammonia, set aside in the cold for three hours, or a longer time if wished. Test a small portion of the filtrate for excess of magnesia mixture by adding a drop of sodium phosphate solution; in the event of there being no precipitate formed, some more magnesia mixture must be added to the solution in order to completely precipitate the phosphoric acid. Filter and wash the precipitate with dilute ammonia, dry, and then ignite in a weighed platinum crucible, and weigh. Before ignition separate the precipitate as thoroughly as possible from the paper; burn the latter separately, and let the ash drop into the cover of the crucible. The precipitate, after ignition, consists of magnesium pyrophosphate, $Mg_2P_2O_7$. The magnesia mixture precipitates ammonium magnesium phosphate, thus:—

$$\underset{\substack{\text{Ammonium}\\\text{phosphate.}}}{Am_3PO_4} + \underset{\substack{\text{Magnesium}\\\text{chloride.}}}{MgCl_2} = \underset{\substack{\text{Magnesium}\\\text{ammonium}\\\text{phosphate.}}}{MgAmPO_4} + \underset{\substack{\text{Ammonium}\\\text{chloride.}}}{2AmCl.}$$

On ignition, the precipitate is decomposed, undergoing the following change:—

$$\underset{\substack{\text{Magnesium}\\\text{ammonium}\\\text{phosphate.}}}{2MgAmPO_4} = \underset{\substack{\text{Magnesium}\\\text{pyrophosphate.}}}{Mg_2P_2O_7} + \underset{\text{Ammonia.}}{2NH_3} + \underset{\text{Water.}}{H_2O.}$$

The reason for completely detaching the precipitate from the filter paper is that the carbon of the paper reduces the phosphate to phosphide, thus lessening its weight.

Magnesium pyrophosphate, $Mg_2P_2O_7$, contains anhydrous phosphoric acid, P_2O_5, combined with two molecules of magnesia, MgO. The molecular weight of the salt, compared with that of the acid, is

$$\overset{Mg_2}{48} + \overset{P_2}{62} + \overset{O_2}{112} = 222. \qquad \overset{P_2}{62} + \overset{O_5}{80} = 142.$$

As 222 by weight of the pyrophosphate contain 142 by weight of phosphoric acid, the weight of the precipitate, whatever it may be, must be multiplied by $142/222 = 0.64$; this gives the phosphoric acid in the quantity taken, and when that quantity has been two-fifths the total solution from 50 grams, the result, on being multiplied by 5, gives the percentage of phosphoric acid.

654. Washing and Ignition of Precipitates.—In all quantitative estimations it must be remembered that none of the substances being worked on must be lost; therefore when transferring a solution or precipitate from one vessel to another, rinse out all remaining traces of the body. Thus, with the yellow precipitate produced by the molybdate, first carefully pour the supernatant solution down a glass rod, as shown in Fig. 82, without disturbing the precipitate. Then fill the beaker with the washing solution and commence filtering. In order to remove the precipitate from the beaker, a small brush made of a quill is very useful. Cut the stem of a quill across near the bottom of the feather end, so as to leave the fibres of the feather projecting beyond the stump. Next cut off all the feather except about an inch at the bottom; then with one cut of a sharp scissors or knife cut the remaining feather part to a width of about a quarter inch. In this way a little brush is made, which readily finds its way round the edge of the bottom of the beaker. For washing purposes the chemist uses a "wash-bottle," as shown in Fig. 83.

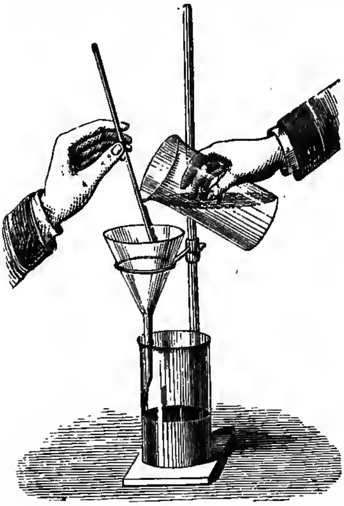


FIG. 82.—Precipitate Washing.

To make a wash-bottle, fit a good cork (india-rubber is preferable) to a 20 or 24-ounce flask. Bore through it two holes, through which pass pieces of glass tubing bent, as shown in the figure; the ends of these tubes must be rounded off; to the left-hand one is attached, by means of india-rubber tubing, a fine glass jet. The length of the tubes must be so arranged that the direction of this jet can be controlled by the forefinger of the hand holding the wash-bottle. To obtain a large stream of water, pour it from the shorter tube; on blowing through the shorter tube a fine stream of water is projected from the jet on the end of the other tube.

FIG. 83.—Wash-Bottle.

The precipitate is usually dried by placing it together with the funnel in the oven. The operation of transferring the precipitate from the paper to the crucible requires great care. First thoroughly clean, and ignite, the crucible and cover; allow them to cool in the desiccator, and weigh. **Crucible and cover must always be weighed together.** While the crucible is cooling get ready a sheet of glazed paper; this should be black for light-coloured precipitates, and yellow for any black precipitates. Trim this paper with either a sharp pair of scissors or knife, so as to produce clean cut edges. Also have in readiness a piece of platinum wire about a foot in length. Clean the bench and spread out the sheet of paper, place on it the crucible and cover. Take the filter paper out of the funnel, fold it together at the top, and *very gently* rub the sides together so as to detach the precipitate. Hold the paper all this while over the glazed sheet; next open the filter and pour its loose contents into the crucible. Having cleaned the paper as thoroughly as possible, fold it into a strip about three-quarters of an inch wide; then roll it up into a coil, and wind the platinum wire tightly round it. Hold the bunsen burner at an angle of 45 degrees over the crucible cover, and burn the paper to an ash in it: the paper will readily leave the wire when burned.

In order to ignite crucibles, they are suspended in triangles; the older form consisted of pieces of common clay pipe, threaded on iron wire, the ends of which were twisted together. Triangles are now very frequently made of fused silica. A *clean* triangle is placed on the ring of the retort stand, and then the crucible placed on it: the crucible is first gently heated by the bunsen, and then more strongly by the foot blowpipe. (For most purposes, a mekker burner may be substituted for the foot-blowpipe). After ignition the crucible is allowed to cool in the desiccator, and then weighed. The weight of the precipitate is obtained by deducting from the gross weight that of the crucible and the filter ash.

655. Weight of Filter Ash.—This determination is usually one of the first made by the chemical student. The best filters hitherto have been those of Swedish make, but now other houses supply filters almost if not quite as good. The most convenient sizes for quantitative work are 2¾, 3½, and 4½ inches diameter. Several packets should be ordered at a time, and it should be stipulated that they shall be from the same parcel of paper. To determine the weight of the ash, take twenty filters, fold and burn them one or two at a time, allowing the ash to drop in a weighed crucible; ignite until a perfectly white ash remains, and again weigh. One twentieth of the weight is taken as that of the ash of a single filter. Provided the various sized filters are of the same paper, the ash of one size may be calculated from that of another. The areas of circles are as the squares of their diameters, consequently the ash of a 4-inch paper would weigh four times as much as that of a 2-inch paper; other diameters could be calculated in the same manner. The weight of ash of filter papers of the better quality is now generally declared on the package. Such weight is usually so small that it may be neglected in ordinary analyses.

656. Potash Estimation.—To a second portion of 100 c.c. of the solution already prepared, add ammonia and *pure* ammonium oxalate in slight excess; filter off the precipitated iron and lime compounds. Evaporate the filtrate to dryness, and ignite gently in order to expel ammonium salts. Dissolve the residue in a small quantity of hot water, filter if necessary, add hydrochloric acid in slight excess, and evaporate to dryness. Dissolve the residue in a very small quantity of water, add some platinum chloride solution and a drop of hydrochloric acid, and evaporate to a sirupy consistency. If the solution lose its orange tint during evaporation, more of the platinum chloride solution must be added. Treat the moist residue with strong alcohol, of a strength of at least 80 per cent., filter off the precipitate on a small counterpoised or weighed filter; wash with alcohol until the washings are colourless. Dry at 100° C. and weigh. The precipitate consists of K_2PtCl_6: 487.7 parts by weight of this body are equivalent to 94 parts of K_2O (potassium oxide). Owing to the great expense of platinum salts, other methods are now frequently adopted, for particulars of which the student is referred to standard works on analysis.

657. Counterpoised and Weighed Filters.—When working on precipitates that are decomposed by a red heat, it becomes necessary to adopt some method other than ignition in a crucible before weighing. It is usual under these circumstances to either weigh or counterpoise the filter beforehand. If the filter is to be weighed, prepare first of all a test-tube shaped stoppered weighing bottle (these can be procured of the apparatus dealer). Dry this in the hot-water oven, cool and weigh. Fold the filter, insert it in the bottle, and dry in the hot-water oven until the weight is constant. The best plan is to set the filter drying over night; the bottle must, of course, be open while in the oven; in the morning stopper it, allow it to cool in the desiccator and weigh. Return to the oven for an hour, and then again weigh; the two weights should agree within a milligram; if not, the drying must be continued until they do. The washed filter and precipitate must first be dried in the oven in the ordinary manner, then transferred to the weighing bottle, and treated exactly as was the original filter. The weight of filter and precipitate, less that of the filter, gives the weight of precipitate. Where the greatest possible accuracy is required this method is to be preferred.

But when speed is an object, a counterpoised filter may be used. Take two Swedish filters, and trim one of the pair until they exactly counterpoise each other when tested on the analytic balance. In this case they are simply to be weighed direct on the pans. Place the one of the papers, folded but unopened, on one side of the funnel, and then put in the other, opened in the usual way. Filter and wash, then dry both filters, and when weighing, again use the empty paper as a counterpoise, placing it on the weight side of the balance. In this method of working, the assumption is that the two papers being of the same weight to start with, and taken from the same lot of filters, will contain the same weight of moisture. Further, that as they are subjected to the same treatment, they will also counterpoise each other at the final weighing. The use of counterpoised filters effects a great saving of time, and yields results of sufficient accuracy for most technical purposes.

658. Determination of Fat.—The fat of meal and flour is estimated by treatment with either ether or rectified light petroleum spirit. Either of these reagents, especially if warm, dissolves fat, together with any traces of resinous matter, with readiness, while none of the other constituents of wheat is soluble in these compounds. In order to effect the estimation, a weighed quantity of the sample is first dried in the hot-water oven, and then treated with repeated quantities of ether or petroleum spirit until a small quantity of the reagent leaves no greasy stain on being evaporated on a piece of white filter paper. If ether be used, that known as "methylated" may be employed. Rectified light petroleum spirit, distilling entirely below 80° C., and leaving no weighable residue, can be purchased from dealers in chemicals for analysis. Both ether and petroleum spirit are extremely volatile and inflammable; both give off at ordinary temperatures an inflammable and explosive vapour. The greatest care must therefore be observed in working with these substances.

659. Soxhlett's Extraction Apparatus.—As ether and petroleum spirit are so volatile and inflammable, special forms of fat extraction apparatus have been devised for this estimation. Their object is to keep the liquids out of contact with the air of the room, and also to make a small quantity of the reagent suffice by repeatedly doing duty. Among the most effective of these apparatus is that devised by Soxhlett, and illustrated in Fig. 84, in which the complete apparatus is shown in section.

Directions will first be given for the fitting up of the apparatus, and then its use and the principles involved therein will be described. The apparatus proper, known familiarly as a "Soxhlett," is that portion *a c;* this is to be procured from the apparatus dealer. Fit the lower end by means of a well-fitting cork into a good Bohemian flask, *n,* preferably one with a rounded bottom, and about four or six ounces capacity. To the top of the Soxhlett, *a,* fit another cork, and through it bore a hole for the tube of a Liebig's condenser, *j k.* The body of this condenser should be from 18 inches to 2 feet in length; the inner tube must have an internal diameter of half an inch, and must not be constricted at the end—these directions are of considerable importance. Fit a cork and bent leading tube to *k.* Fit up a four ounce flask, *m,* with a cork through which passes a leading tube and two-bulbed thistle funnel, *l.* Pour sufficient mercury in this funnel to just fill the space between the two bulbs. Instead of this flask and funnel, *m l,* a small **U**-tube, about ⅜ inch diameter, and with limbs 5 inches long, may be employed. By means of a piece of glass tubing bent to shape, this **U**-tube may be corked direct to the top of the condenser, *k,* and then sufficient mercury added to just cover the bend. The whole apparatus is then self-contained, which is a decided advantage. With a condenser of ample length this mercury arrangement may be entirely dispensed with, and the top of the condenser tube simply covered with a test-tube or small beaker. The more modern spiral worm condenser may with advantage be substituted for the older straight tube Liebig. A small water bath, *o,* is also required.

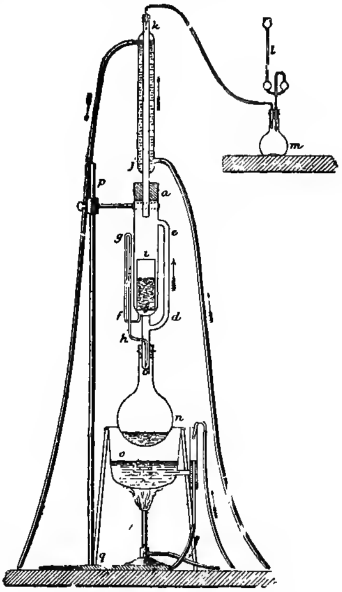


Fig. 84.—Soxhlett's Extraction Apparatus.

Dry 10 or 20 grams of the meal or flour for one or two hours in the hot-water oven, taking as much as can conveniently be placed in the apparatus. Take a square piece of Swedish filter paper, big enough to fold up into a little cylindrical case, *i b.* Fold this so that no liquid can escape through the case except through the pores of the paper, even when full. This specially folded filter is easily prepared by taking the end of a ruler, or other flat-ended cylinder, placing the end in the middle of the paper, then doubling it across the diagonals, and folding the corners round the ruler. Transfer the meal to the filter, and drop this into the Soxhlett.

For flours, instead of this folded filter, it is convenient to use a small glass percolator: this is easily made by taking a piece of glass tubing of such a size as to drop easily into the Soxhlett, and cutting it to about the same length as the case, *i b*. A piece of filter paper is then tied securely to the lower end. Ether percolates through flours with extreme slowness; and consequently, when a paper case is used, much of the ether simply finds its way through the sides of the case, without penetrating the interior of the mass of flour. Attach the Soxhlett to the flask, *n,* and place it on the bath. Next see that all lights are extinguished within 10 or 12 feet of the apparatus. Bring the ether or petroleum spirit from an outer store-room, and pour it in the Soxhlett through a funnel until the level of the liquid rises to *g*; it will then syphon over into the flask *n*. Next pour in about an ounce more of the liquid, and at once, before doing anything else, carry the ether or spirit back to the store-room. Next attach the condenser, *j k,* and push in the corks as tightly as possible. Support the apparatus by means of a retort stand, *p q r,* and ring. If using the flask, *m,* place it on a shelf conveniently near and connect the leading tube at *k* to that of the flask by means of a piece of india-rubber tubing. Connect the lower end of the condenser to a water tap by means of india-rubber tubing, and arrange another piece to the upper end to take the waste water to the drain. Bring a water supply to the bath, and also fix an india-rubber tube leading to the drain. Arrange a bunsen underneath the bath. Before going further, once more examine each cork and joint, to see that all are air-tight. Turn on a stream of water through the condenser. Next light the bunsen, and keep it going with a gentle flame. The ether will soon boil; when it does so, arrange the flame so as to keep it boiling steadily, but not too violently. The ether vapour ascends through *d e,* and drives the air before it up through the condenser, and out of the flask, *m*, through the mercury in the funnel, *l*. As soon as the ether vapour reaches the condenser, it is condensed and runs back in a small stream, dropping into the filter, *i b*. The complete condensation is furthered by the use of the mercury funnel, which offers a slight resistance, and thus prevents the escape of ether while still allowing a passage for air. As the condensed ether drops, the body of the Soxhlett fills up to the level of *g*; the ether then returns to the flask by means of the syphon, *f g h*. It carries back with it the fat it has dissolved out of the meal; as the ether continues boiling in *n,* pure ether is continuously distilled over the fat remaining in the flask. By this treatment one quantity of ether can be made to act on the same meal an indefinite number of times. If all the joints are in good condition, no odour of ether will be observed during the whole of the time the apparatus is in work. The apparatus may be allowed to remain in action for an hour or more. Turn out the bunsen underneath the bath, and also all other lights in the vicinity. Take the apparatus to pieces, cork up the lower flask; test a drop of the ether remaining in the Soxhlett, in order to see if it contains any fat by allowing it to fall on a piece of white filter paper, when it should produce no stain.

The ether solution requires next to be evaporated to dryness and the fat weighed.

660. Treatment of Ethereal Solution.—Having obtained an ethereal or petroleum spirit solution, containing all the fat in the sample being analysed, filter if not perfectly clear. It will be next necessary to drive off the solvent, and thus procure the fat in a suitable state for weighing. Take, for the purpose of evaporation, one of the counterpoised glass dishes, and tare it in the balance, making a note of its weight against the counterpoise. It must here again be mentioned that ether vapour is not only inflammable, but also highly explosive when mixed with air. In default of special apparatus for the purpose, heat the water-bath to boiling, and then take it into a room in which there are no lights. Partly fill the dish with the ether solution, place it in the bath, and allow it to evaporate spontaneously, refill from time to time from the flask, and finally rinse the flask with a little pure ether, pouring the rinsings into the dish. If necessary, heat some more water and replace that in the bath as it becomes cool. When most of the solvent, whether ether or petroleum spirit, has been thus driven off, place the dish in the oven, heat for two or three hours, and then weigh until constant. Well ventilate the room before any lights are brought in. By this method the whole of the ether used is lost; but if wished the greater part may be recovered by connecting the flask by means of a cork and leading tube to a condenser and distilling off most of the ether, after which the concentrated fatty solution may be poured from the flask into the dish, and then the flask rinsed out with successive very small quantities of ether. Some operators prefer to use instead of the flask *n*, a small conical flask, which is itself weighed. The whole of the ether is then distilled off, and the residue dried off to constant weight in the flask itself.

CHAPTER XXIII.

SOLUBLE EXTRACT, ACIDITY, AND PROTEINS.

661. **Soluble Extract.**—The proportion of a meal or flour soluble in cold water is of importance in judging of the character of a sample. This soluble portion is termed the "soluble extract," or "cold aqueous extract," and consists of the soluble proteins, sugars (maltose and sucrose), gum (dextrin), soluble starch, and soluble inorganic constituents of the grain, principally potassium phosphate. The solution made for the purpose of this estimation is also available for the determination of the acidity and soluble proteins. On the addition of even cold water to a flour or meal, chemical action immediately commences, the soluble starch being dissolved out of any abraded or ruptured starch granules, and acted on by any diastase present. As a consequence, the soluble extract varies with the time the solution is allowed to stand in contact with the flour or meal; absolute uniformity must therefore be adopted in the method employed for making this soluble extract. The following is a convenient standard method:—Weight out 25 grams of the flour, and transfer to a clean dry flask of from 500-700 c.c. capacity, add 250 c.c. of cold distilled water, cork the flask with a clean cork, and shake up vigorously for five minutes by the clock. One or two minutes' shaking is sufficient to break up any little balls of flour, but in order to ensure perfect solution the longer time is recommended. Next, let the flask stand for 25 minutes, making half-an-hour from the time of commencement. In the meantime arrange a 10-inch coarse filter paper, in a funnel 5 inches in diameter, both being quite dry, and place a clean dry beaker or flask to receive the filtrate. At the end of the half-hour most of the insoluble portion of the flour will have subsided; remove the cork and carefully decant as much as possible of the supernatant liquid on to the filter *without* disturbing the sediment. The filtrate will at first be cloudy; return it to the filter until quite clear, then collect for analysis. By working in this way, there being practically none of the solid matter of the flour on the filter, any subsequent changes in the wet flour do not affect the results. As the speed of filtering varies with different filter papers, it was often found, when both flour and water were placed on the filter together, that a higher extract was yielded by the same flour, simply as a result of a slower filtering paper; there is a further disadvantage in that, when any of the solid matter of the flour was allowed to get on the filter, it greatly impeded the rapidity of filtering. Twenty-five c.c. of this clear filtrate must next be evaporated to dryness in order to ascertain the amount of matter it holds in solution. The glass dishes that were used for the moistures are also well adapted for this purpose. Having tared a clean dish against its counterpoise, and noted any difference in weight, pour 25 c.c. of the filtrate into the dish, and evaporate to dryness over the water-bath.

For all practical purposes, any soluble extract obtained by the above process may be regarded as pre-existing in the soluble state in the flour, as in baking operations there can be no difference between matter already soluble and matter rendered soluble by other agents present in the flour during the period elapsing before filtration.

In case it is required to differentiate between the soluble and readily rendered soluble matters of flour, the diastase of the flour may first be destroyed by boiling the flour with 95 per cent. alcohol. The moisture in the flour must first be determined, as it has to be allowed for in arranging the strength of the alcohol employed. The operation may be carried out in the following manner:—Weigh out 25 grams of the flour, containing say 12 per cent. of moisture; 25 grams must obviously contain 3 grams of water. As 5 c.c. of water will reduce 95 c.c. of absolute alcohol to 95 per cent. strength, then the water present in 25 grams of flour will reduce a proportionate quantity,

As 5 : 3 :: 95 : 57 c.c. absolute alcohol.

In a clean dry flask add 57 c.c. of absolute alcohol to the flour, or other quantity as calculated from the moisture. This alcohol will then be of 95 per cent. strength. Next add a further 100 c.c. of previously prepared 95 per cent. alcohol, and boil for an hour, after fitting to the flask a return condenser so as to restore the alcohol. Next filter and air-dry the flour, then transfer to a flask and determine soluble extract as previously directed.

662. Water-Bath.—This consists of a vessel, usually of copper, about 4 inches deep, and of other dimensions varying with the number of dishes for which it is made. In case of a bath specially prepared for flour extracts and similar work, one to hold 12 dishes is a convenient size; its actual dimensions would then be 12 in. × 15 in. × 4 in. The top contains a series of holes about 2¼ ins. diameter, one for each dish; to each of these is fitted a cover. A water supply apparatus, similar to that used with the hot-water oven, is attached to the side of the bath. It is very convenient to have a series of flanged glass rings to drop into these holes, on which the dishes are placed; they are thus prevented from coming in actual contact with the metal. These rings are similar in shape to the top of a beaker, and are about an inch deep; in fact, the tops of broken beakers are often cut off and utilised for this purpose. They must be of such a diameter that they just fit in the holes of the bath, being supported by their flanges. The reason for their use is that the outsides of the dishes are liable to pick up foreign matter from the metal of the bath, and so have their weight increased. When the dishes are allowed to come in contact with the metal of the bath, they must be carefully wiped clean before being dried. In use, the hot-water bath should have its feed apparatus so regulated as to maintain the water in the bath at a depth of about half an inch; the water must be kept boiling at a moderate rate by means of a bunsen burner. The evaporation of the fluid in the dishes then proceeds by the action of the steam.

663. Soluble Extract, continued.—On the contents of the dish having evaporated to dryness, place it in the hot-water oven for 24 hours, and then weigh. In order to calculate the percentage of soluble extract, it must be remembered that by adding 250 c.c. of water to 25 grams of flour a 10 per cent. filtered solution has been prepared. It follows that 25 c.c. of the solution contains the soluble extract of 2.5 grams of flour; the weight must therefore be multiplied by 40 in order to give the percentage. It ought to be mentioned that in strictness this is not quite correct, as no allowance is made for the moisture of the flour, so that, as 25 grams of flour contain about 3 grams of water, we really have more nearly 253 c.c. than 250 of water present. As, however, the results are only used for comparative purposes, this is not of practical importance. If wished, the soluble extract may be calculated out to the exact quantity, when the percentage of moisture has been ascertained.

664. Acidimetry and Alkalimetry.—The measurement of the amount of either free acid or free alkali in a solution is often an operation of considerable chemical importance. Thus, in flours or meals, the acidity is occasionally determined; the measure of acidity being often a useful help in deciding whether or not a sample of flour or wheat is unsound. Flours which contain bran or germ develop acidity much more rapidly than those thoroughly purified from the offal. This developed acidity is caused usually by the presence of lactic acid, and is produced, as has been previously stated, by the action of the lactic ferment. This organism is always found in greater or less numbers on the bran and germ of the grain, and acts by converting the sugar into lactic acid. This action is much favoured by damp and warmth.

665. Normal Solutions: Sodium Carbonate.—The progess of acidimetry (acid measuring) belongs to the department of volumetric analysis, and hence it becomes necessary to explain some of the terms used in that branch of analytic work. There is required a set of standard acids and alkalies; that is, solutions of known and definite strengths, and an indicator. The standard solutions are usually made up to normal strength. It is requisite that the exact meaning of this term *normal* should be understood. Normal solutions are prepared so that one litre at 16° C. shall contain the hydrogen equivalent of the active reagent, weighed in grams. It follows that normal solutions of acids and alkalies are all of the same strength, and that equal quantities exactly neutralise each other. Decinormal solutions are prepared by diluting normal solutions to one-tenth their original strength, and are shortly designated at N/10 solutions. The acid and alkali most commonly used are sulphuric acid, H_2SO_4, and sodium hydroxide (caustic soda), NaHO. Both these substances are extremely deliquescent, and so cannot be easily weighed with accuracy. It is customary, therefore, first to make up as a starting point a normal solution of sodium carbonate, Na_2CO_3. Directions follow for starting from this point and making up the necessary solutions.

Normal sodium carbonate contains 53 grams of the dry salt to the litre; as this solution is seldom employed for any other purpose than that of preparing other solutions, a quarter of a litre only need be made. Take about 18 to 20 grams of the pure dry salt, heat to dull redness in a platinum dish or crucible for about 15 minutes, allow to cool under the desiccator, and then weigh out exactly 13.25 grams. Transfer this weight to a 250 c.c. flask, and two-thirds fill with water, shake up until the whole of the salt is dissolved, and then fill up the flask to the graduation mark. Keep the solution in a clean dry stoppered bottle.

666. Indicators.—The next step is, with the aid of this solution, to make up a solution of normal sulphuric acid. From a study of elementary chemistry, the student already knows that it is usual to determine whether or not a substance is acid or alkaline by observing its action on litmus. Acids turn a solution of that body red, the blue colour being restored by excess of alkali; when the solution is neutral its colour is violet. Bodies such as litmus, which are used in order to determine the completion of any particular action, are termed "indicators."

Litmus.—To prepare the litmus solution, take some litmus grains and boil with distilled water; let the liquid stand for some hours, and decant off the clear supernatant solution. Let this solution again boil, and add nitric acid, drop by drop, until it assumes a reddish-violet colour; boil for a time, and the colour once more becomes blue. Continue this treatment with nitric acid until a violet tint is obtained that remains permanent after boiling. The reason for this boiling is that the litmus contains some earthy and alkaline carbonates; the carbon dioxide liberated, on addition of an acid, gives the litmus a reddish tint, and so requires to be expelled by boiling. The litmus solution should be kept in an open bottle supplied with a small dropping pipette, by which a small quantity can be removed when wanted. If this litmus solution be kept in a closed bottle it is apt to become colourless; the colour may be restored by pouring the solution in an evaporating dish, and thus exposing it for a short time to the action of the atmosphere.

Phenolphthalein.—Another indicator, much more delicate than litmus, is phenolphthalein; this body, however, possesses the disadvantage of being unsuitable in the presence of carbon dioxide or ammonia. Phenolphthalein is a white or brownish powder, of which one part is dissolved in 30 parts of 90 per cent. alcohol, and one or two drops of the solution employed for each estimation. The addition of phenolphthalein to an acid solution produces no colour, but with the slightest excess of alkali an intense magenta red is produced.

Methyl Orange.—Under this name is prepared another body, also most useful as an indicator. It is a yellowish brown powder, one part of which may be dissolved in 30 parts of 90 per cent. alcohol, and two or three drops employed for each estimation. In alkaline solutions methyl orange has a yellow tint, which changes to pink or red with the slightest excess of acid. Methyl orange is absolutely unaffected by carbonic acid, and also by organic acids. On the other hand, it is sensitive to the action of ammonia, and is well adapted for titrating that body. A curious result of the action of these last two indicators is that water from chalk or limestone formations containing calcium carbonate in solution reacts alkaline to methyl orange and acid to phenolphthalein. The dissolved carbonate affects the methyl orange, which is insensible to the carbonic acid, while the phenolphthalein is caused to give an acid reaction by the excess of carbonic acid present.

667. Normal Sulphuric Acid.—Of normal and decinormal acids and alkalies, two litres of each is a convenient quantity to prepare; these solutions are best kept in stoppered Winchester quarts, which hold just over the two litres. Normal sulphuric acid contains 49 grams of H_2SO_4 to the litre. Take about 65 to 70 c.c. of pure sulphuric acid of 1.840 specific gravity (*i.e.,* strongest acid of commerce), mix this with four or five times its volume of water, allow to cool, and then make up to exactly two litres with distilled water. With acid of full strength the solution will now be too strong; it must next be tested against the normal sodium carbonate. Fill a 50 c.c. burette with the acid solution; with a pipette pour 20 c.c. of the normal sodium carbonate into a porcelain evaporating basin, and add two or three drops of methyl orange. Note the height of the acid in the burette and proceed to add it cautiously, little by little, to the carbonate in the dish. Wait between each addition until the effervescence is over. Continue adding the acid until the neutral tint between yellow and pink is reached. Read the height of the acid in the burette, deduct the first reading; the difference is the amount of acid required to neutralise the 20 c.c. of normal sodium carbonate. Let us suppose that this amount is 18.65 c.c., then as with normal solutions equal quantities should exactly neutralise each other, it is evident that the 18.65 c.c. require to be made up with distilled water to 20 c.c.; that is, $20 - 18.65 = 1.35$ c.c. of water must be added. Measure the total quantity of acid solution there is, and add water to it in the above proportion. Suppose that there remain 1950 c.c., then as $18.65 : 1950 :: 1.35 :$ to the quantity of water that must be added. Add the proper amount of water to the solution, shake up thoroughly, and once more test by filling the burette and titrating against 20 c.c. of the normal sodium carbonate, exactly as before described: 20 c.c. of the one solution should exactly neutralise 20 c.c. of the other. It should be explained that the term *titrating* is applied to the operation of testing a solution by adding to it a volumetric reagent.

668. **Normal Sodium Hydroxide.**—The next step is to prepare a solution of normal sodium hydroxide; this solution contains 40 grams of pure NaHO to the litre. Weigh out about 120 grams of pure caustic soda of commerce, and dissolve up in a beaker in the smallest possible quantity of hot water. Allow the solution to stand for some time, in order that any sediment present may subside; cover the beaker during this time with a glass plate. By means of a pipette, draw off as much as possible of the clear solution, and dilute it down to two litres. Run in this solution from a burette into 20 c.c. of the normal sulphuric acid using phenolphthalein as an indicator. With the quantity directed the solution will be too strong. Calculate the amount of water that must be added to bring the solution to its normal strength, and proceed exactly as was directed with the normal acid. After dilution, again titrate acid against alkali, when 20 c.c. of the one must exactly neutralise 20 c.c. of the other.

669. **Decinormal and Centinormal Solutions.**—Having succeeded in preparing with accuracy the normal sulphuric acid and sodium hydroxide, decinormal solutions of these reagents must be made. Measure out by means of a 100 c.c. pipette, 200 c.c. of the normal acid, and pour it into the litre flask; fill up to the graduation mark with distilled water, and pour into a clean dry "Winchester quart," next add another litre of distilled water, and two litres of decinormal acid are prepared. In the same manner make up two litres of decinormal soda. Titrate 20 c.c. of one of these against the other; these, too, should become exactly neutral when mixed in equal quantities.

Centinormal solutions are occasionally required for certain purposes of analysis. They may be readily prepared by taking 100 c.c. of decinormal solutions, and diluting down to a litre with distilled water free from carbon dioxide.

670. **Water Free from Carbon Dioxide.**—In addition to the reagents already described, it is necessary to have, for determinations of acidity in flours or meals, some distilled water free from carbon dioxide. This is readily obtained by first rendering some water alkaline with caustic soda, and then distilling; the first portion of the distillate should be rejected. The caustic soda combines with the carbon dioxide that may be dissolved in the water; and so by this treatment the gas is prevented from coming over with the condensed steam. The water should be tested in order to see that no soda has been carried over mechanically by too violent boiling. The water must give no colouration on the addition of two or three drops of phenolphthalein to 100 c.c., but should strike a distinct and permanent pink on the addition of a drop of $N/10$ soda.

For many purposes it is sufficient to boil ordinary distilled water for some ten or fifteen minutes before use, by which most of the carbon dioxide is expelled.

671. **Acidity of Meals or Flours.**—When it is desired to make this estimation, the aqueous infusion should be made with the water free from carbon dioxide. Pour 100 c.c. of aqueous infusion into a white porcelain

dish, add two or three drops of phenolphthalein solution, and proceed to titrate with $N/10$ soda. The burette must be read before the soda is run out, and then again at the completion of the reaction. After the addition of each drop of soda, stir the liquid thoroughly; the reaction is complete when the slightest pink shade remains permanent after stirring. It need scarcely be said that the dishes and other apparatus must be perfectly clean; the burette should first be rinsed with clean water, and then with a few c.c. of the soda solution; this should be allowed to run away, and then the instrument should be filled. Soda solutions tend to cause glass stopcocks to set fast; the burette must therefore be washed after use, and before being put away the stopcock should be withdrawn and wrapped round with a small piece of paper, and again put in its place; this prevents its sticking. It must of course be seen that it is not so placed as to drop out by an accident and get broken. For soda solutions it is preferable, however, to use a burette with an india-rubber tube and spring clip. Assuming that the acidity of meal or flour is due to lactic acid (see remarks on page 331 as to causes of acidity and sourness in flour and bread), then as 1 c.c. of $N/10$ NaHO is neutralised by 0.009 gram of lactic acid, the No. of c.c. used × 0.009 gives the weight of lactic acid in 100 c.c. of the infusion. This quantity of infusion contains the acid of 10 grams of the meal or flour, therefore No. of c.c. of $N/10$ soda $\times 0.009 \times 10 =$ percentage of acid in the sample—in other words, with the quantities directed the percentage equals 0.09 times the No. of c.c. of $N/10$ soda used.

Balland, who has devoted much attention to the acidity of flours, finds that, on exhausting a good flour with alcohol and titrating the solution with turmeric paper as an indicator, the normal acidity represented as sulphuric acid varies between 0.015 and 0.040 per cent. But working with the whole flour a higher percentage of acidity is obtained. Planchon took 5 grams of the flour and gradually mixed same with 50 c.c. of cold distilled water, and added, when perfectly homogeneous, two or three drops of alcoholic phenolphthalein solution and titrated with $N/20$ solution of sodium hydrate. He used 0.0245 as a factor, and multiplying the number of c.c. of soda by that figure, got what was in his opinion the actual acidity of the flour. He finds that this does not increase during the time necessary for the estimation; but on the contrary, that no variation occurs during the first two hours. Taking the same flour, and maintaining it in contact with water for varying times, he got the results which are appended. A corresponding series of tests was made with the filtered aqueous extract of such flours: the results obtained are given in the following table as soluble acidity.

	Percentage of acidity reckoned as H_2SO_4.	
	Total.	Soluble.
Titrated immediately	0.110	0.0107
" after 1 hour	0.110	0.0225
" " 2 hours	0.110	0.0230
" " 4 "	0.113	0.0250
" " 7 "	0.115	0.0275
" " 24 "	0.126	0.0425
" " 48 "	0.145	0.0830

The same flour, when extracted with alcohol (rectified spirit) for 24 hours, showed after filtration the presence of 0.03 per cent. of acidity soluble therein. Flour does not give up the whole of its acidity immediately to either water or alcohol. Planchon, therefore, recommends instead the titration of the whole flour in the presence of water, and gives the following as the results of such tests, still reckoning total acidity as sulphuric acid:—

	Acidity per cent.
Nine Roller Milled samples of fresh flour ..	from 0.105 to 0.122
Stone Milled sample of fresh flour	0.119
Second sample of do.	0.133
Damaged flour unfit for use	0.160
Second sample of do.	0.565

The authors may state that they have for some time independently adopted the method of titration of the whole substance for both flour and bread testing, and confirm the conclusions arrived at by Planchon.

The mode of titration of the mixed flour and water is performed in just the same way as with the filtered aqueous extract.

672. Estimation of Proteins.—For technical purposes, proteins are now determined by what is known, after the name of the inventor, as Kjeldahl's process, (or some modification thereof). This method depends on the fact that, when an organic substance is heated with a mixture of concentrated sulphuric acid and potassium sulphate, its nitrogen, if any, is (with very few exceptions) converted into ammonia, and retained by the acid as ammonium sulphate. The residuum is subsequently rendered alkaline by excess of soda, and distilled. The ammonia comes over and is collected in a known volume of decinormal acid, which is titrated, and then the amount of ammonia determined. From this the percentage of protein matter is readily calculated. A detailed description follows of the mode of performing an organic nitrogen estimation by Kjeldahl's method.

Reagents and solutions required.—Pure concentrated sulphuric acid, as free as possible from nitrogen compounds.

Concentrated solution of caustic soda. Take 3 lbs. of commercial sodium hydroxide, either in powder or sticks, and dissolve in as small a quantity of water as possible; let the solution cool, and make up to sufficient to fill a Winchester quart (about two Imperial quarts). Store in a Winchester fitted with india-rubber stopper.

Powdered potassium sulphate. Heat this for some time in an iron vessel, and store in a stoppered bottle.

Decinormal sulphuric acid and sodium hydroxide.

Methyl orange solution.

Apparatus.—Special long-necked heating flasks of Jena toughened glass, of 300 or 500 c.c. capacity. Wrought-iron stand to hold four of these flasks for heating purposes. This stand should consist of a stout sheet iron plate, 15 inches long by 4½ inches wide, supported on four legs for ordinary bunsen burners, and with four holes, each 2 inches diameter, through the plate. On the one long edge of the plate an upright back should be fixed about 4 inches high, and with round notches cut out so that when the flasks are resting in the holes in the plate, the necks may lie in the notches in the back. The flasks are thus supported when in use in an oblique position.

Distilling Apparatus.—If 500 c.c. flasks are used, these may be employed direct for the distillation. If not, a 500 c.c. flask of the same kind should be used for this operation. To this flask, *a,* in Fig. 85, fit a rubber cork and splash-head, *b.* This latter is attached in turn to a condenser, *c,* fitted with a condensing tube of pure tin. The lower end of the condenser, *d,* is passed through a rubber cork, and thus fixed to the Kjeldahl bulbs, *e f.*

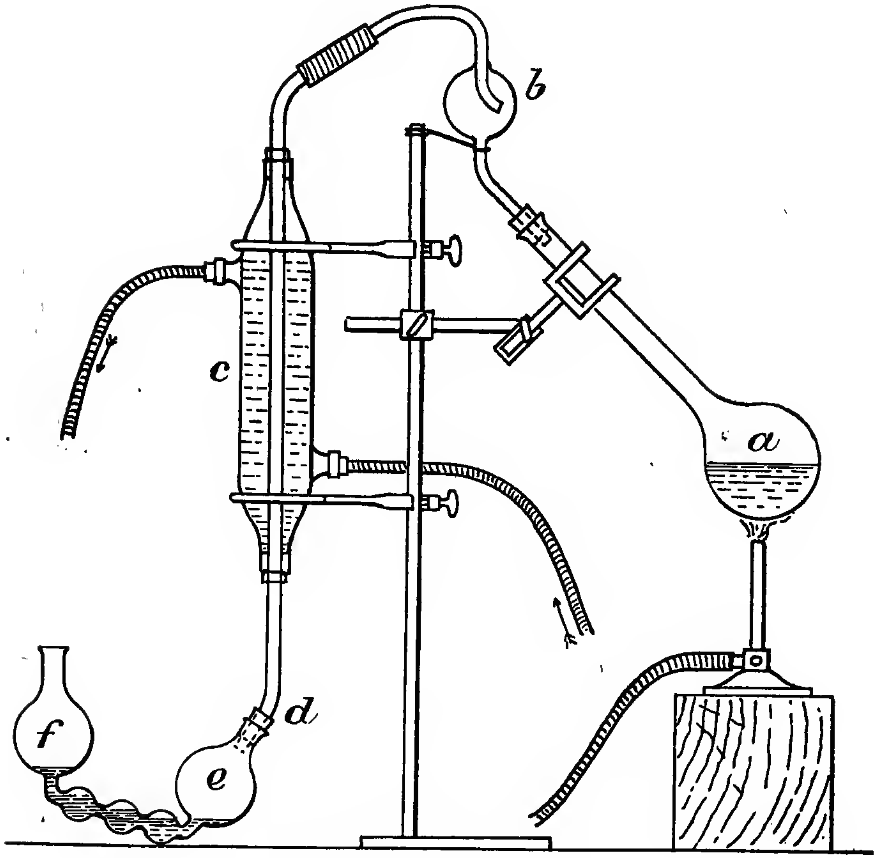


FIG. 85.—Kjeldahl Distilling Apparatus.

Mode of Analysis.—To estimate total proteins on flours or meals, weigh off 1 gram of the sample and transfer it to a clean, dry heating flask. The weighing is best done with a pair of counterpoised horn dishes for the balance. Obtain a wide-mouthed glass funnel that will just fit the flask, and pour into it the flour or meal, carefully brushing every particle in by means of a brush kept for the purpose. Or if preferred, make a **V**-shaped gutter out of glazed paper that will pass right into the neck of the flask and down into the bulb, and introduce the substance by means of this. In any case all particles must be brushed right down into the flask. By means of a pipette add 20 c.c. of the concentrated sulphuric acid and about 10 grams of the potassium sulphate. This latter may be conveniently measured, using for that purpose the end of a test tube, or what answers very well, a sewing thimble of the right size. (This may be obtained once for all by weighing out the quantity.) Rinse the acid gently round inside the flask, so as to thoroughly wet it, taking care that there are no dry patches of flour between the acid and the flask. Occasionally one gets a small patch which obstinately refuses to mix with the acid, which must then be provided for in the heating. Arrange the flask stand in a stink cupboard designed so as to carry off the fumes produced, and stand the flask obliquely in one of the holes, with its neck lying in the notch. Should there be any adherent dry patches of flour, turn the flask so that they are out of the liquid and on the upper side of the flask. Turn on a very small bunsen flame; as the acid gets hot it carbonises the flour. which froths up and gradually subsides into a tarry looking liquid. The steam of the boiling acid attacks any flour patches on the upper part of the flask, and speedily brings them down into the solution. Continue to apply heat so that the acid is just below the point of ebullition, a bubble of steam escaping only occasionally: the black liquid gradually loses its colour, and in about 45 minutes has usually become colourless. As soon as this stage is reached it is allowed to cool.

When perfectly cold the next step is to arrange for the distillation: this, however, must be preceded by a blank experiment, made in order to determine the amount of ammonia present as impurity in the reagents used. Add 20 c.c. of the concentrated sulphuric acid to the contents of the 10 gram measure of potassium sulphate in a round-bottomed flask precisely as before: heat so as to melt the sulphate, and allow to cool. Measure off 200 c.c. of water in a graduated jar, and pour it into the flask containing the acid and sulphate—the liquid becomes very hot, but does not spurt if sufficient water is added. Next add a drop of methyl orange, and give the flask a shake round so as to mix the contents. Then by means of a funnel pour some of the strong soda solution from a 100 c.c. graduated measure into the flask until the acid is neutralised, and add an extra 5 c.c. Make a note on the label of the bottle of the total quantity thus used. (The object of adding methyl orange is to determine once for all how much soda is necessary; this quantity is then used in the estimations until a fresh quantity is made up, when it should be again titrated.) Introduce a few fragments of coarsely granulated zinc in order to prevent bumping, and cork up the flask to the splash-head, *b*. By means of a pipette, introduce 25 c.c. of decinormal sulphuric acid into the bulbs, *e f*, and connect to the condenser. Turn a current of cold water through the condenser, and light a bunsen underneath the flask; its contents speedily come to the boil, and the steam and ammonia together are condensed, and retained in the Kjeldahl bulbs, *f e*. Continue the distillation until about 200 c.c. have come over; turn out the lights, disconnect the bulbs, and pour their contents into an evaporating basin, and titrate with decinormal soda and methyl orange. In the blank experiment, the quantity of ammonia evolved amounts usually from 0.3 to 0.5 c.c. of decinormal ammonia: make a note of this quantity, and repeat the blank with each new lot of concentrated acid and soda. So far as possible make these up each time in about equivalent quantities.

Returning to the clear solution obtained by treatment of the flour or meal with acid and sulphate as previously described, if a 500 c.c. flask has been used, add water to it in the same way as to the blank, and then the quantity of strong soda solution as ascertained, then the granulated zinc and distil as before. If the burning down with acid and sulphate has been carried out in a 300 c.c. flask, the cold contents must first have 150 c.c. of water added to them, and then be transferred to a 500 c.c. flask. With the remaining 50 c.c. of water give the 300 c.c. flask several rinsings, which must be added to the main portion in the larger flask, after which the requisite quantity of soda is poured in. As soon as the soda is added, the ammonia is set free and therefore no time should be lost in corking the flask to the splash-head in order to prevent any escape. At the close of the experiment thoroughly wash out the distillation flask and place it bottom upwards in a rack so as to drain. Preserve the washed zinc in a small bottle or flask of water for use in the next test.

Calculation.—As 25 c.c. of acid are taken for the determination in the bulbs, that quantity, less the amount required for its titration, represents the amount of decinormal ammonia evolved, thus:—

25 c.c. — 13.3 c.c. $N/10$ soda = 11.7 c.c. $N/10$ NH_3.
(According to blank experiment, the correction is 0.4 c.c.)
then 11.7 — 0.4 = 11.3 c.c. from nitrogen of flour.

As 1 c.c. of $N/10$ NH_3 equals 0.0014 of nitrogen as ammonia, then 11.3 × 0.0014 = 0.01582 of nitrogen.

Osborne and Voorhees find that gliadin contains 17.66 per cent. of nitrogen, and glutenin 17.49 per cent. As these two proteins constitute the main portion of the proteins of flour, they assume wheat proteins to contain 17.60 per cent. of nitrogen. As $\frac{100}{17.6} = 5.68$, they multiply the quantity of nitrogen found by 5.68, as a constant factor in order to convert the percentage of nitrogen into that of proteins. Proteins as commonly separated contain a quantity of water of hydration which is not driven off at 100° C., and therefore multiplication by 5.68 does not give the quantity of hydrated proteins. The figure formerly employed for calculating of nitrogen into hydrated proteins was 6.33, but this is now regarded as being more correctly expressed by 6.25. As this last factor, 6.25, has been very extensively employed, it is still most commonly used so as to make results comparable with those already on record. In returning analytic results, the actual quantity of nitrogen found, and also the factor used for calculation into proteins, should be stated.

Returning to the 0.01582 gram of nitrogen obtained in the experiment, then

0.01582 × 5.68 = 0.0898 gram of true proteins.
0.01582 × 6.25 = 0.0989 gram of hydrated proteins.

These are the quantities in 1 gram of flour, and therefore these quantities × 100 = 8.98 per cent. of true proteins, and 9.89 per cent. of hydrated proteins respectively.

As 0.0014 and 5.68, and 6.25, respectively are constants, their respective products, 0.00795 and 0.00875, may be used as factors. Therefore the number of c.c. of decinormal acid neutralised by the evolved ammonia × 0.00795 gives the weight of true proteins, and × 0.00875 gives the weight of hydrated proteins, in the quantity taken for analysis.

673. True Gluten Estimation.—For this purpose take about 0.15 gram of dry gluten, weigh it accurately, and treat with acid and sulphate as with the whole flour. Conduct the whole estimation precisely as before; then, number of c.c. of NH_3 evolved × 0.00875 = weight of true gluten (hydrated proteins) in the quantity of dry gluten taken. The following data show the mode of calculation:—

Flour yields 13.10 per cent. of dry crude gluten.
Taken for true gluten estimation — 0.152 gram.
Ammonia evolved, less correction, 14.6 c.c.
14.6 × 0.00875 = 0.12775 gram true gluten.

As the whole flour contained 13.10 per cent. of true gluten, then:
As 0.152 : 13.10 :: 0.12775 = 11.01 per cent. of true gluten.

Therefore:

$$\frac{\text{Percentage of crude gluten} \times \text{true gluten found in estimation}}{\text{Crude gluten used for estimation}} =$$

percentage of true gluten in whole flour.

In order to test the "True Gluten" determinations the following experiment was made:—Four glutens were extracted from the same flour, one being washed, as well as could be judged, to the right degree of purity; two of the others were purposely underwashed, and the fourth overwashed. The following were the results in wet and dry glutens:—

	Wet Gluten.	Dry Gluten.	True Gluten.
No. 1. Washed correctly ..	53.0 per cent.	16.1 per cent.	15.0 per cent.
No. 2. Insufficiently washed	63.0 "	20.0 "	15.1 "
No. 3. Would pass for being washed sufficiently	56.7 "	16.8 "	15.1 "
No. 4. Lost weight beyond No. 1 with very great difficulty ..	48.5 "	15.1 "	14.7 "

Note No. 4 was weighed when at 51 per cent., and again washed in clean water; this water on testing gave starch colouration with iodine solution, showing that even at 51 per cent. starch was still present. Notwithstanding the wide differences in crude gluten between Nos. 1, 2, and 3, the true gluten is practically identical in all. In No. 4, however, the protein itself is being lost. This was an exceptionally tough, hard, glutenous flour, or doubtless there would have been an appreciable difference in true gluten between Nos. 1 and 2. In true gluten estimations it is recommended that where the true gluten does not amount to 80 per cent. of the crude gluten, another estimation be made of the crude gluten and the first one rejected.

674. Estimation of Soluble Proteins.—To make this estimation, take 50 c.c. of the filtered solution as prepared for soluble extract, and evaporate to dryness in one of the acid flasks. For this purpose the flask should be placed in the hot-water oven, as, unless the whole flask is kept hot recondensation occurs. Even in the hot-water oven evaporation proceeds but slowly; it may be considerably hastened by immersing the flask in a bath composed of water with a large excess of potassium carbonate. This easily maintains a temperature of 110-115° C. Treat the dry residue in the flask with acid and sulphate, and proceed in the usual manner. It should be remembered that 50 c.c. contain the soluble proteins of 5 grams of the flour.

675. Gliadin Estimations; Classification of Methods.—Serious objections have been taken to gluten estimations on the ground that they cannot afford a true determination of the total protein content of the flour; and therefore it is urged that they should be dispensed with and instead a determination made of the nitrogen of the flour and the percentage of protein obtained by calculation. Most of the investigations on this matter have been conducted with reference to the strength of flour, and accordingly the various researches and conclusions based thereon have been fully described in Chapter XIV. dealing with that subject. That chapter should be carefully read as an introduction to the whole question of gliadin determinations. If gluten determinations cannot yield a true indication of the protein content of flour, it follows that the protein content cannot yield a true indication of the gluten content of the flour. From what has preceded, it will be seen that the authors regard that agglomerate of various flour constituents, which is called gluten, as being the factor which in virtue of its quantity and quality largely dominates the properties of a flour. That body can be determined with considerable accuracy by a simple physical operation, and possesses well-marked physical characteristics. They therefore attach importance to its estimation. It being known that gluten is largely composed of glutenin and gliadin, and that these bodies may roughly be compared to the sand and lime in a sample of mortar, one being the component which gives substance and the other the constituent which acts as a binding agent, it would seem that the relative proportions of each must exert a considerable effect on the qualities of gluten. Accordingly, the effect of such relative proportions has received most careful examination. Certain earlier observers, as for example Guthrie and Fleurent, attached considerable importance to the proportions of each, and have suggested the bearing which they have on the character of flour. Others, among whom are included Snyder and Wood, have arrived at the conclusion that flours cannot be differentiated in quality according to the proportions of gliadin and glutenin. Thus Snyder finds that gliadin may range from 45 to 70 per cent. of the total protein, without the flour being affected in any but a minor degree. Almost every one of those who have investigated the problem has adopted a different method of determination, and therefore no very direct comparisons can be made. Further, from time to time, each operator has modified his own methods as possible improvements have suggested themselves. The methods adopted divide themselves into (1) direct estimations on the flour, and (2) estimations made on the washed out gluten. Each of these merits some little examination in detail.

676. Gliadin Estimations on Flour.—On treating flour with 70 per cent. alcohol, the gliadin, together with some portion of the water-soluble proteins, as well as the soluble carbohydrates and soluble ash, is dissolved out. It is therefore not possible to estimate gliadin by direct weighing of the residue from the evaporated filtered solution, but instead, recourse must be had to a nitrogen determination on the filtrate by the Kjeldahl process. As an example of American methods the following description by Teller is given:—"Two grams of the flour are put in a flask of about 150 c.c. capacity, 100 c.c. of dilute alcohol, specific gravity 0.90, are then added to the flour, care being taken to mix the flour well with a small quantity of the alcohol before the entire amount is added. The flask is then set aside at room temperature for 24 hours, shaking occasionally to assure thorough extraction of the gliadin. The liquid is then filtered and 50 c.c. of the clear filtrate taken for determination of nitrogen. The alcohol should be evaporated off on the steam bath before the sulphuric acid is added to avoid charring of the alcohol. The nitrogen obtained is then multiplied by the factor 5.7, or, as we find it more convenient in our laboratories here, the number of c.c. of decinormal acid obtained for each gram of flour is multiplied by the factor 0.8. This gives the per cent. of gluten or gliadin direct. In our commercial work here we determine the gluten by the Kjeldahl method, using 1 gram of flour and multiplying the titration of ammonia obtained by the factor 0.8 as given above. We find this to give as nearly the true amount of gluten in the flour as can be done by the most careful hand washing, and it is much more reliable when the work is done by different operators on different days."—(*Personal communication*, May, 1910.)

The method adopted by the authors is substantially the same as that of Teller, except that, following more closely on the lines of Chamberlain, they use hot 70 per cent. alcohol, and take 400 c.c. to 4 grams of flour, (a quantity which may be somewhat in excess of that absolutely necessary.) They shake frequently during the 24 hours, or preferably shake continuously in a shaking machine, a description of which is subsequently given in paragraph 677. After filtration, 200 c.c. of the clear filtrate are placed in a 500 c.c. long necked Jena flask. This is immersed in a bath of potassium carbonate and water, and connected to a spiral condenser. The alcohol is distilled off, and then the flask is disconnected and the heating continued until the solution is evaporated to dryness. This takes place rapidly with the bath at 110-115° C. The Kjeldahl determination is then made on the residue, and the results calculated in the usual way.

In a paper, previously quoted, Teller has shown that alcohol of 0.90 specific gravity, *i.e.*, 57 per cent. strength, dissolves more nitrogenous matter from flour than does 70 per cent. spirit. This points to the fact that the dilute alcohol takes up some of the water-soluble proteins in addition to gliadin proper. Chamberlain also states that hot alcohol dissolves out less protein than does cold, and therefore recommends the latter. This again is an indication that other protein than gliadin is being dissolved, since gliadin is more readily dissolved on the application of heat than in the cold: on the other hand proteins of the albumin type become less soluble because of coagulation. It is important also to consider the bearing of the length of time of extraction in view of the nature of the solvent, a dilute solution of alcohol not being capable of inhibiting proteolytic action. Air-dried gliadin is "*very soluble*" in 70 per cent. alcohol, and must be at least equally soluble in the finely divided condition in which it naturally occurs in flour. With the use of a very large excess of the solvent, it would seem that the increase of protein dissolved by greatly prolonged extraction is not merely gliadin, but contains in addition alcohol soluble protein produced by proteolytic action on protein matter, which at the outset is insoluble in the dilute alcohol. Corroboration of this is afforded by the fact that when dough is allowed to stand under conditions which favour proteolytic action, there is a marked increase in the quantity of dilute alcohol soluble protein. The method employed must be regarded as a measure of the amount of protein dissolved in dilute alcohol under certain definite conditions, but evidently is not a measure of gliadin only. Another point which has to be considered is that according to Chamberlain, of the total gliadin and glutenin contained in the wheat and flour, only about 85 per cent. can be obtained as gluten by the washing process. On this the question arises whether this balance of 15 per cent. is a loss due to inherent faultiness of the gluten washing process, or whether it is the result of some of the gliadin and glutenin being in a non-adhesive condition and therefore not functioning as gluten. This matter has been already discussed (see paragraph 439), and if the authors' view be correct, then flour contains some gliadin which would be determined as such in a direct estimation on the flour, and yet is not contributing to its strength.

677. **Gliadin Estimations on Wet Gluten.**—The foregoing considerations have caused the authors to incline to determinations made on the wet gluten itself as being more likely to have a direct bearing on the problem of the quality of gluten and its effect on the strength of flour. In gluten-washing those bodies which do not go to the building up of that india-rubber like body are eliminated. The soluble carbohydrates and ash have been more or less removed, and also such soluble proteins as are not retained by the absorptive power of the gluten proteins. If therefore the alcohol solvent be applied to this body it can only extract what is practically soluble protein and the small amount of mineral bodies which is inherently associated with this substance.

From its physical nature, gluten is a difficult body to treat with a solvent. As the result of a long series of experiments the authors adopted the method of triturating with starch and then extracting the gliadin. The following is a description of the method employed:

Quantities, 2.2 grams wet gluten, 11 grams of spirit-washed starch, 400 c.c. of 70 per cent. alcohol.

In order to obtain a fairly pure wheat starch, 1,000 grams were taken and washed with about 4 litres of hot 70 per cent. alcohol in the shaking machine for 24 hours. The starch was filtered from the spirit, pressed fairly dry, and again washed with a similar quantity of hot 70 per cent. alcohol for another 24 hours in the machine, and filtered and pressed. A third washing was then given with 95 per cent. alcohol in the same way, after which the pressed starch was carefully air-dried in a warm room. This is termed spirit-washed starch.

After measuring the alcohol, 10 c.c. were reserved, and the remainder raised to the boiling point. In practice, this was done by connecting the flask to a return spiral condenser, so that there was no loss on the spirit commencing to boil. The weighed gluten and about half the starch were then placed in the mortar and ground up with a few drops of the reserved alcohol into a thin dough. This was stiffened by the addition of a little more starch, and the grinding continued, a little more alcohol was then added, and so as again to make a thin dough, and then a little more starch. By this alternate addition of starch and alcohol, the gluten was rapidly disintegrated, and finally was obtained as a perfectly smooth dough. This was carefully transferred into a shaking bottle of 1 litre capacity. Any cold alcohol remaining was added, and then the alcohol from the flask, which by that time will have got to the boil. The bottle was then at once introduced into the shaking machine, where in practice it remained about eighteen hours.

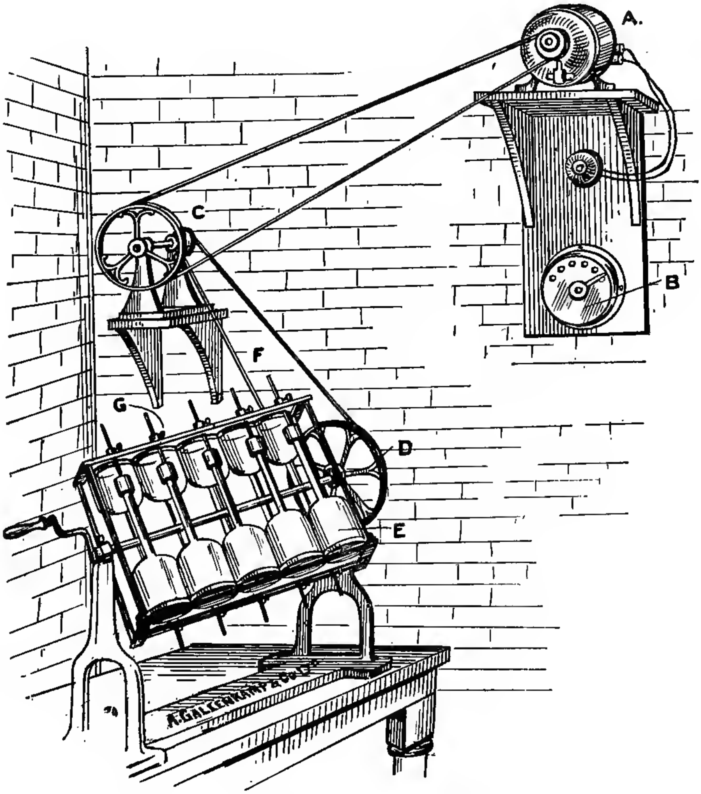


Fig. 86.—Shaking Apparatus.

The following is a description of illustration, Fig. 86, of the installation of shaking apparatus employed by the authors. When electricity is available, the most convenient source of power is a small electric motor A. This is started and regulated by the graduated switch, B. In order to slow down the speed, the motor is geared up with a countershaft, C; which in turn drives the main pulley, D, of the shaking machine. The machine is made to hold six or ten bottles, each of which stands in a socket, E, of the right size. The sliding cap, F, is then placed down to hold the bottle securely, and screwed in position by the screw, G. The switch must be turned on so as to give the machine about sixty revolutions per minute. As the machine revolves, the contents of the bottle fall from the bottom to the top, and back again, about once a second.

At the close of the shaking period, the bottle is removed, and the liquid poured on to a dry 10-inch filter. It filters very quickly and runs through quite bright. If 364 c.c. of the filtrate be taken, that quantity is equivalent to 2 grams of wet gluten. In order to save the spirit, the filtrate is boiled down in a flask connected to a condenser until the whole of the alcohol has distilled off. For this purpose the flask should be immersed in a hot bath of potassium carbonate solution; in this the spirit boils rapidly, and the gliadin does not stick to the flask. The remainder in the flask is then transferred to a weighed glass basin and evaporated to dryness. The necessary starch correction is made and the results calculated as gliadin *ex* gluten. The weight of residuum thus obtained is a very convenient one (about 0.30 to 0.35 gram), but lesser quantities may be taken if wished. For example, 1.1 grams of gluten, 5.5 grams of starch, and 100 c.c. of alcohol may be used for each test. Then, on evaporation of 91 c.c. of the filtrate, the gliadin *ex* 1.0 gram of gluten is obtained.

678. Application of Gluten and Gliadin Tests to Commercial Flours.—In order to illustrate the application of the various gluten and other tests to modern flours, the authors obtained a range of commercial samples from the same millers, which are numbered according to grade, No. 1 being the highest.

The following are the results of analysis:—

PROTEIN AND OTHER ESTIMATIONS OF VARIOUS COMMERCIAL FLOURS.

Numbers—.	1.	2.	3.	4.	5.
Percentages on Flour.					
Wet Gluten	32.83	34.36	35.47	34.67	34.77
Ratio of Wet to Dry Gluten	3.0	3.0	3.0	3.1	3.0
Dry Gluten	10.72	11.28	11.72	11.09	11.56
Non-Protein Matter in Dry Gluten	2.19	3.12	3.39	3.20	3.26
True Gluten	8.53	8.16	8.33	7.89	8.30
Gliadin *ex* Gluten	5.30	5.45	5.41	5.41	5.54
Glutenin *ex* Gluten	3.23	2.71	2.92	2.48	2.76
Percentages on Dry Gluten.					
Non-Protein Matter in Dry Gluten	20.43	27.66	28.92	29.76	28.20
Gliadin	49.44	48.31	46.16	48.78	47.92
Glutenin	30.13	24.03	24.92	21.46	23.88
Percentages on Flour.					
Total Proteins	9.53	9.80	10.06	9.71	10.58
Gliadin *ex* Flour	5.29	5.20	5.38	5.25	5.40
Non-Gliadin Proteins (Glutenin, Albumin, etc.)	4.24	4.60	4.68	4.46	5.18
Percentages on Total Proteins.					
Gliadin *ex* Flour	55.51	53.06	53.48	54.07	51.04
Non-Gliadin Proteins	44.49	46.94	46.52	45.93	48.96
Recovered as True Gluten	89.51	83.26	82.80	81.25	78.45
Not recovered as True Gluten	10.49	16.74	17.20	18.75	21.55
Percentages on Flour.					
Moisture	14.56	14.52	14.38	14.40	14.06
Ash	0.38	0.36	0.42	0.44	0.52
Water absorption, Quarts per Sack	60	62	62	63	63

In these flours the total gluten increases as the colour goes down, and keeps pace with their strength, but in true gluten No. 1 is slightly higher than any of the others. The gliadin in No. 1 is rather a higher proportion of the dry gluten than in any of the other flours. Looking at the total proteins as determined direct on the flour they run closely parallel to the dry glutens. The gliadins as obtained from the flour run very closely to each other, being highest in No. 1 and lowest in No. 5. The percentage of proteins not recovered as true gluten steadily increases as the flours diminish in quality. It would seem therefore that a comparison of the total proteins with the proportion thereof recoverable as true gluten has a close connection with the grade of flour. The ash in all the flours is low, and precludes the possibility of mineral additions to the flour. The flours likewise gave no reaction when tested for the presence of bleaching agents. As might be expected with flours from the one mill, there is a close general resemblance between the whole of the grades.

679. Gluten and Gliadin Tests on Special Flours and Wheats.—The various gluten and allied tests were also applied to a series of single wheat flours, and typical wheats, with the following results. The wheat determinations were made on the finely ground meal of the whole grain, but in order to make the data obtained somewhat more comparable with those on flours, they have also been calculated to amounts present in 70 per cent. straight-run flours from such wheats.

Single Wheat Flours.

6. From strong spring American wheat.
7. ,, French wheat, grown in England, 1910 crop.
8. ,, Karachi wheat, 1910 crop.
9. ,, Taganrog wheat, 1909 crop.
10. ,, Bar-russo wheat, 1910 crop.
11. ,, New Russian wheat, 1910 crop.
12. Fourteen years old strong American flour.

Protein and other Estimations on Single Wheat Flours.

Numbers—	6.	7.	8.	9.	10.	11.	12.
Percentages on Flour.							
Wet Gluten	42.30	29.90	23.47	25.73	37.70	32.90	47.27
Ratio of Wet to Dry Gluten ..	2.8	3.0	3.4	3.0	3.3	3.3	5.1
Dry Gluten	15.02	9.75	6.77	8.52	11.34	9.98	9.20
Non-Protein Matter in Dry Gluten	4.25	1.95	1.40	0.90	2.07	1.63	6.13
True Gluten	10.77	7.80	5.37	7.62	9.27	8.35	3.07
Gliadin *ex* Gluten	7.36	4.98	3.75	3.49	6.91	5.75	2.84
Glutenin *ex* Gluten	3.41	2.82	1.62	4.13	2.36	2.60	0.23
Percentages on Dry Gluten.							
Non-Protein Matter in Dry Gluten	28.29	20.00	20.68	10.56	18.25	16.33	66.63
Gliadin	49.00	51.07	55.38	40.96	60.93	57.61	30.87
Glutenin	22.71	28.93	23.94	48.48	20.82	26.06	2.50
Percentages on Flour.							
Total Proteins	12.95	10.19	8.14	13.78	11.46	12.12	13.15
Gliadin *ex* Flour	6.43	5.25	3.82	7.63	5.64	6.34	5.75
Non-Gliadin Proteins	6.52	4.94	4.32	6.15	5.82	5.38	7.40
Percentages on Total Proteins.							
Gliadin *ex* Flour	49.65	51.52	46.93	55.37	49.21	52.31	43.72
Non-Gliadin Proteins	50.35	48.48	53.07	44.63	50.79	47.69	56.28
Recovered as True Gluten ..	83.16	76.54	65.97	55.30	80.89	68.89	23.34
Not recovered as True Gluten..	16.84	23.46	34.03	44.70	19.11	31.11	76.66
Moisture, per cent. of flour ..	—	12.86	12.14	12.00	12.70	12.60	12.46
Water Absorption, Quarts per Sack	70	67.0	71.0	69.5	70.0	68.5	—

WHEATS.

13. Old Odessa, 1909 crop.
14. New Odessa, 1910 crop.
15. Manitoba.
16. Northern Plate (Rosario Santa Fé).
17. American Durum.
18. English Rivetts.
19. "Azima" (Russian).
20. "Ulka" (Russian).

PROTEIN AND OTHER ESTIMATIONS ON TYPICAL WHEATS.

Numbers—.	13.	14.	15.	16.	17.	18.	19.	20.
Percentages on Meal.								
Wet Gluten	33.27	25.50	34.65	35.70	28.85	18.50	31.35	40.50
Ratio of Wet to Dry Gluten	3.0	2.7	2.9	3.0	2.9	3.0	3.1	3.1
Dry Gluten	10.96	9.49	11.88	11.86	10.00	6.21	10.07	12.98
Non-Protein Matter in Dry Gluten	1.96	2.04	2.54	2.23	2.40	1.26	1.94	3.30
True Gluten	9.00	7.45	9.34	9.63	7.60	4.95	8.13	9.68
Gliadin *ex* Gluten ..	4.64	3.68	5.54	5.73	4.68	2.81	4.98	6.07
Glutenin *ex* Gluten ..	4.36	3.77	3.80	3.90	2.92	2.14	3.15	3.61
Percentages on Dry Gluten.								
Non-Protein Matter in Dry Gluten	17.88	21.49	21.38	18.80	24.00	20.29	19.26	25.42
Gliadin	42.33	38.78	46.63	48.31	46.80	45.25	49.45	46.76
Glutenin	39.79	39.73	31.99	32.89	29.20	34.46	31.29	27.92
Percentages on Meal.								
Total Protein	13.24	12.11	13.41	13.73	13.70	8.81	11.22	13.86
Gliadin *ex* Meal ..	5.07	4.11	5.60	5.99	4.15	2.97	4.76	5.38
Non-Gliadin Proteins ..	8.17	8.00	7.81	7.74	9.65	5.84	6.46	8.48
Percentages on Total Proteins.								
Gliadin *ex* Meal ..	38.29	33.94	41.76	43.63	30.29	33.71	42.42	38.82
Non-Gliadin Proteins ..	61.71	66.06	58.24	56.37	69.71	66.29	57.58	61.18
Recovered as True Gluten	67.97	61.52	69.65	70.21	55.47	56.18	72.46	69.69
Not recovered as True Gluten	32.03	38.48	30.35	29.79	44.53	43.82	27.54	30.31
Calculated on 70 per cent. Straight Flours.								
Wet Gluten	47.53	36.43	49.50	51.00	41.21	26.43	45.00	57.86
Dry Gluten	15.66	13.56	16.97	16.94	14.28	8.87	14.38	18.54
Non-Protein Matter in Dry Gluten	2.80	2.91	3.63	3.18	3.43	1.80	2.77	4.71
True Gluten	12.86	10.64	13.63	13.76	10.86	7.07	11.61	13.83
Gliadin *ex* Gluten ..	6.63	5.26	7.91	8.18	6.68	4.01	7.11	8.67
Glutenin *ex* Gluten ..	6.23	5.38	5.72	5.58	4.18	3.06	4.50	5.16

On examining the results on single wheat flours, excluding No. 12 for the moment, No. 6 gave the highest percentage of wet gluten, while Barrusso, No. 10, was the next highest. The spring American was also highest in dry gluten, while No. 8, Karachi, was the lowest. In this particular flour the ratio of wet to dry gluten is very high; Wood's researches (paragraphs 430 *et seq.*) go to show that the more water there is in the gluten the nearer it is to actual disintegration. The absolute amount of gliadin *ex* gluten was high in both Nos. 6 and 10, while low in No. 8. But the relative proportion of the whole dry gluten which consisted of gliadin was comparatively high in No. 8. Comparing the total proteins with the dry gluten, No. 9 was the highest in the former and almost the lowest in the latter. Taganrog, No. 9, was very difficult to wash for gluten; there was considerable frothing, and the wet gluten was very friable throughout the whole operation of separation. This flour is from a very hard wheat, and one which alone does not make a good loaf. The gliadin *ex* gluten content was very low. On the other hand the gliadin *ex* flour was high. Taking Nos. 6 and 9, protein and gliadin determinations on the flour would place No. 9 the higher; but gluten and gliadin *ex* gluten estimations at once show the marked superiority of the spring American flour.

No. 12 sample, called "Fourteen Years Old Strong American Flour," is of rather special interest. A number of years ago, one of the authors made some experiments on the feasibility of compressing flour into solid blocks by hydraulic pressure of several tons to the square inch. Among flours thus tested was a sample of strong American flour, of which several blocks were preserved. These, after 14 years, were quite free from any mould or visible signs of decomposition, and a portion was accordingly subjected to this series of tests. On washing for gluten the dough broke down into a flocculent non-coherent deposit, and evidently was physically quite unfitted for bread-making. By repeated washings on a hair sieve, and squeezing and coaxing the particles together, a flabby and scarcely coherent mass of wet gluten was obtained, which gave the unusually high percentage of 47.27. However, most of this was evidently water, the ratio being 5.1, and the total quantity of dry gluten 9.20 per cent. Pursuing the investigation of the dry gluten a step further, it contained only 3.07 per cent. of true gluten, 6.13 per cent. consisting of non-separated starch. Nearly all the true gluten was composed of gliadin, the whole of the glutenin having disappeared. On turning to the direct determinations on flour, the proteins are high and are very nearly the same as in the strong American flour, No. 6; 13.15 against 12.95 per cent. The gliadin *ex* flour is very nearly as much as that of No. 6, 5.75 against 6.43 per cent., and would in ordinary analysis call for no very special remark. It shows up rather more in percentages on total proteins, where the figure is 43.72 against 49.65 in the No. 6 flour. But, according to Snyder (paragraph 426), this difference lies almost within the normal range since the same type of flour may have variations of proteins soluble in alcohol from 45 to as high as 70 per cent. with only minor variations in the bread-making value of the flour. The importance of these comparisons lies in the fact that the ordinary protein and gliadin *ex* flour tests scarcely serve to differentiate a spring American flour of the highest quality from a flour of the same origin, but so profoundly altered by fourteen years age as to have completely lost the physical properties so essentially characteristic of wheaten flour. On the other hand the abnormal character of this fourteen-year-old flour is at once revealed by an ordinary gluten test, and is in evidence throughout the whole series of subsidiary tests on the wet gluten. This is in striking contrast with Chamberlain's conclusion that "the determination of gluten is not able to yield any information that cannot be gained either from the determination of total proteins or that of the alcohol-soluble and insoluble proteins." It is submitted that if what may be called the purely chemical tests (*i.e.*, protein and gliadin determinations on the flour direct) fail so signally to indicate such remarkable differences as there are between these two flours, then they can be even less depended on as a means of gauging and estimating minor differences in character and quality. The gluten tests and their developments, on the contrary, afford exceedingly valuable information as to the general baking properties of the flour.

The wheats range from the strongest Manitoban to one of the weakest of English wheats, Rivetts. The first pair, Nos. 13 and 14, consist of

Odessa of two successive years' crops. The old was very satisfactory, but the new wheat was the reverse. The former was higher in wet, dry, and true gluten. Also the relative proportion of gliadin *ex* gluten was higher in the older wheat. The total proteins and gliadin *ex* meal were in general accordance with the gluten series of tests. The calculated percentages on 70 per cent. straight flours are introduced with the object of showing approximately the composition of the flours from the wheats, and permitting same to be compared with other flours. The Manitoba wheat, No. 15, is high in wet and dry gluten, and also in true gluten. The gliadin is high both absolutely, 5.54 per cent., and relatively, 46.63 per cent., of the dry gluten. On the meal, the total proteins, 13.41, and gliadin, 5.60 per cent., are also high. Throughout the whole series of tests the Rosario Santa Fé very closely resembles Manitoba wheats. The American Durum, No. 17, refuses to come into line with any of the others. The wet and dry glutens are low, so also is the true gluten, 7.60 per cent. But the gliadin *ex* gluten is relatively high, being 46.80 per cent. of the dry gluten. Gluten testing would reveal the fact that this wheat was extremely hard; and this, coupled with the low gluten, would indicate thorough conditioning of same before grinding. The total proteins of this wheat are high, 13.70, while the proportion recovered as true gluten was low, being only 55.47 per cent. The gliadin *ex* meal is very low. The extreme hardness of the grain very materially affects all estimations made by solvents direct on the meal, and therefore gluten and gliadin *ex* meal are both abnormally low. If the wheat be softened by standing some time after the addition of water, these soluble constituents would show an increase. Similarly, the great hardness of the wheat would react adversely on the flour if untreated, whereas effective conditioning would very materially improve the flour. The English Rivetts, No. 18, is almost the antithesis of the preceding flour. Its gluten throughout is low, 18.50 per cent. wet, but contains a fairly high proportion of gliadin, 45.25 per cent. The total proteins agree, being so low as 8.81 per cent., while the gliadin *ex* meal is down to 33.71 per cent. of the total proteins. The Azima, No. 19, has a fair gluten, with a relatively high percentage of gliadin *ex* gluten. The total proteins occupy a medium position, while the gliadin *ex* meal is also fairly high. The Ulka wheat, No. 20, is distinguished by a very high percentage of wet gluten, of a soft and what is sometimes called "pappy" character. The ratio of wet to dry gluten is high, 3.1, but the dry gluten is nevertheless the highest of the series, 12.98 per cent. The true gluten, 9.68, is also the highest of those in the table. The gliadin *ex* gluten is high absolutely, 6.07, and medium relatively, being 46.76 per cent. of the dry gluten. In total proteins this wheat is also the highest of the series with 13.86 per cent., while relatively the gliadin *ex* meal is rather above the average with 38.82 per cent.

CHAPTER XXIV.

ESTIMATION OF CARBOHYDRATES, AND ANALYSIS OF BODIES CONTAINING SAME.

680. Estimation of Sugar by Fehling's Solution.—The composition and properties of the sugars are fully described in Chapter VI. It is there shown that maltose is capable of forming a red precipitate of copper sub-oxide in the reagent termed Fehling's solution, while dextrin and starch cause no precipitate. (See, however, Brown and Millar's conclusion that dextrin has a reducing power of about R. 5.8, paragraphs 180 and 263.) This reaction is not only of service in testing for maltose and certain other sugars, but also serves the purpose of quantitatively determining the amount of sugar present in a solution.

As before, directions are first given for the preparation of the reagents, and then for the performance of the analytic operation.

681. Fehling's Standard Copper Solution.—Powder a sufficient quantity of pure re-crystallised copper sulphate, and dry it by pressure between folds of filter paper. Weigh out 69.28 grams, dissolve in water, add 1 c.c. of pure sulphuric acid, and make up the solution to 1 litre.

682. Alkaline Tartrate Solution.—Weigh out 350 grams of pure Rochelle Salt (potassium sodium tartrate), and dissolve so as to make about 700 c.c. of solution. Filter if necessary. Next dissolve 100 grams of sticks of pure caustic soda in 200 c.c. of water. If the solution is not clear, it must be filtered through a funnel fitted with a plug of glass wool. Mix the two solutions together, and make up the volume to 1 litre.

When required for use, these solutions must be mixed together in equal proportions; they then form the original Fehling's solution. This solution possessed the disadvantage of changing in character by being kept; and hence the modification in which the Rochelle salt is only added to the copper sulphate immediately before the solution is required for use. Each c.c. of the mixed solution contains 0.03464 gram of copper sulphate, and was formerly considered equivalent to exactly 0.005 gram of pure dry glucose.

683. Action of Sugars on Fehling's Solution.—A careful investigation has been made by Soxhlett of the action on Fehling's solution of specially pure specimens of the various types of sugars: he finds as a result that the amount of precipitate formed depends not only on the quantity of sugar present, but also on the degree of concentration of the solution, the temperature at which the determination is made, and other conditions. Hence great care must be taken to work always in precisely the same manner, as it is only by so doing that comparative results are obtained.

Sugar may be determined by Fehling's solution either gravimetrically or volumetrically. A description of the gravimetric method is first given. The student should commence by practising the estimation on cane sugar, as this substance is easily obtained in a condition of purity. Cane sugar has no action on Fehling's solution, but when heated gently with dilute acid is changed, by hydrolysis, into a mixture of glucose and fructose in equal quantities, viz.:—

$$\underset{\text{Cane Sugar.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Glucose.}}{C_6H_{12}O_6} + \underset{\text{Fructose.}}{C_6H_{12}O_6}.$$

Glucose and fructose both act on Fehling's solution, precipitating copper sub-oxide Cu_2O, in definite quantity.

684. Gravimetric Method on Cane Sugar.—Procure some of the sugar known as coffee crystals; this is the variety of sugar sold by the grocer for use with coffee, and consists of large, colourless, well-defined crystals of almost pure cane sugar. Select some of these free from extraneous matter, powder them, and dry for a short time in the hot-water oven. Make up a one per cent. solution by weighing out 1 gram of the pure dry sugar, dissolving it in water, and making up the volume to 100 c.c. Take 50 c.c. of this solution, and add to it 5 c.c. of pure fuming hydrochloric acid. For this purpose it is best to use a flask graduated at 50 and 55 c.c. Place the flask in a water bath, and heat until it reaches the temperature of 68° C.; this operation should be arranged so as to occupy about 10 minutes. Next pour the contents of the flask into a 100 c.c. flask, and dissolve in it dry sodium hydroxide in small quantities at a time until the solution is *slightly* alkaline, testing after each addition with a small strip of litmus paper. Cool the flask and make up the contents to 100 c.c. with water. The flask now contains a 0.5 per cent. alkaline solution of cane sugar converted into glucose and fructose. Add 25 c.c. of Fehling's standard copper solution to the same quantity of alkaline tartrate solution, and mix the two thoroughly. Take two beakers of about 6 ounces capacity, and pour into each 25 c.c. of the mixed Fehling's solution. Next add to each 50 c.c. of boiling distilled water that has been boiling for about half an hour. Stand the beakers in a water bath, the water of which is kept boiling by a bunsen; allow them to stand for 7 minutes, and then look to see that no precipitate has formed. Should a precipitate occur, the Fehling's solution is impure, and is consequently no longer fit for use. Next add to each beaker 20 c.c. of the 0.5 per cent. sugar solution and replace in the water bath for 12 minutes. The precipitated cuprous oxide is best weighed on a counterpoised filter; prepare, therefore, beforehand, two pairs of small Swedish filters, trimmed until each one of the pair exactly counterpoises the other, when tested in the analytic balance. Fold one of the pair of counterpoised filters, and filter the copper oxide rapidly from the solution; the filtrate should still be of a deep blue colour. Collect the filtrate in a porcelain evaporating basin, and examine carefully in order to see if any traces of the precipitate have found their way through the paper; if so, pour away the supernatant liquid from the basin, and wash any precipitate back on to the filter. Moisten the other of the pair of counterpoised filters with some of the filtrate, and wash both the filters rapidly with boiling water, and dry both in the hot-water oven. The reason for treating the second paper with some of the filtrate is to cause each to be in as nearly as possible the same condition, so that it (the second) shall still counterpoise the first paper after being washed and dried. The filters should be dried for 12 hours and then weighed, the counterpoise paper being placed on the weight side.

If wished, the cuprous oxide may be converted into cupric oxide and weighed as such. Or the oxide may be reduced to copper, either by the action of hydrogen or by electrolytic processes, and weighed in the metallic, form. For these and other methods, consult *Allen's Commercial Organic Analysis*, vol. i.

In order to understand the calculations involved in the estimation of sugar by Fehling's solutions, it will be necessary for the student to make himself thoroughly acquainted with the properties of the sugars as already described.

The glucose and fructose produced by the action of dilute acid on cane sugar, as shown in the equation in a preceding paragraph, are sometimes grouped together as glucose, or grape sugar; it is then said that one molecule of cane sugar (sucrose) produces, when inverted, two molecules of glucose. From the equation it will be seen that the molecular weight of cane sugar is 342, while that of the glucose formed is 360. It was formerly supposed that an exact number of molecules of CuO of the copper sulphate was reduced to Cu_2O by the sugar; hence we find the statement that two molecules of glucose reduce 10 CuO to 5 Cu_2O. Soxhlett's researches, however, show that the reaction is not so simple, but, as before stated, varies, being dependent on the degree of the dilution of the reagent and other conditions. Different kinds of sugar, too, under the same conditions, reduce, weight for weight, different quantities of CuO to Cu_2O. Working in the manner directed, the reducing power of sugar on Fehling's solution is, according to determinations by O'Sullivan and others:—

Cane Sugar has no reducing action.	1 gram produces	and reduces
Glucose	1.983 grams of Cu_2O	2.205 of CuO.
Cane Sugar after inversion ..	2.087 „ „	2.315 „
Maltose	1.238 „ „	1.378 „

The reason why the inverted cane sugar produces more Cu_2O than does glucose is, that 1 gram of cane sugar, on inversion, yields more than a gram of glucose, the exact quantity being 1.052 grams. When only the one variety of sugar is present in a solution, the following factors may be used for calculating the amount of sugar from the weight of precipitated Cu_2O.

Glucose	$^1/_{1\cdot983} = 0.5042$
Cane Sugar after inversion	$^1/_{2\cdot087} = 0.4791$
Maltose	$^1/_{1\cdot238} = 0.8077$

Thus, suppose that in the analysis made with the 0.5 per cent. solution, the weight of the precipitated Cu_2O was 0.2075 grams, then

$$0.2075 \times 0.4791 = 0.0994 \text{ of cane sugar.}$$

Theoretically, in 20 c.c. of the 0.5 per cent. solution there is 0.1 gram of sugar; the results of the analysis give 99.43 per cent. of chemically pure sugar. If the estimation were made with perfect accuracy, this would show that the sugar contained 0.57 per cent. of moisture or other impurity; the deficiency is doubtless in part due to error of analysis. The duplicate estimations made should agree closely.

When making an analysis of a substance, the composition of which is known approximately, a quantity should be taken that contains as nearly as can be calculated 0.1 gram of inverted cane sugar, or 0.2 gram of maltose. In case the estimation shows that the amount of sugar differs widely from these quantities, a second determination must be made in which more or less of the substance is taken.

In the presence of other carbohydrates capable of inversion by hydrochloric acid, O'Sullivan recommends that cane sugar be inverted by means of invertase, which is without action on the other sugars, etc., which may possibly be present. The method is described in detail in connection with the analysis of malt extract.

685. Volumetric Method on Cane Sugar.—When Fehling's solution is intended only to be used gravimetrically, its exact strength is not a matter of great importance, but when employed for volumetric estimations, its strength must first be accurately determined by titration with a standard solution of sugar. For this purpose the 0.5 per cent. solution of inverted cane sugar already described may be used. The sugar must be added to the Fehling's solution, and not the Fehling's solution to the sugar. The sugar solution is therefore placed in a burette, and in order that its contents may not get heated during the operation, the glass jet is attached by means of a piece of india-rubber tubing about 8 or 10 inches long. The burette may then be placed so as not to be vertically over the basin in which the Fehling's solution is being heated.

Measure out 5 c.c. each of the standard copper and alkaline tartrate solutions into a white porcelain evaporating basin; add 40 c.c. of well-boiled boiling water, and heat the liquid quickly to the boiling point by means of a small bunsen flame. In order to test the purity of the Fehling's solution, boil for 2 minutes; there should neither be a precipitate nor any alteration of colour. Next add the sugar solution in small quantities at a time, boiling between each addition. As the operation proceeds, the deep blue colour of the solution disappears; towards the end, add the sugar more cautiously, and after each boiling allow the precipitate to subside. Tilt the dish slightly over, note whether the clear supernatant liquid is still of a blue tint by observing the white sides of the dish through it. When the colour has entirely disappeared, the reaction is complete. The exact point may be determined with more exactitude by means of a dilute solution of potassium ferrocyanide, acidulated with acetic acid. With a glass rod put a series of drops of this reagent on a white porcelain tile; wash the rod, take out a drop of the clear liquid from the dish with it, and add it to one of the drops of the ferrocyanide; the slightest trace of copper produces a reddish-brown colouration.

The results of the first estimation must only be looked on as approximate, but having thus gained an idea of about how much sugar is required, the succeeding ones may be made more quickly, as almost all the sugar may be added at one time. Thus, if 9.6 c.c. of sugar solution were required in the first trial, then in the second from 8.5 to 9.0 c.c. may be run in at once, and then the solution added more carefully as the end of the reaction is reached.

Provided the Fehling's solution is of normal strength, then

10 c.c. = 0.0500 grams of glucose or invert sugar.
10 c.c. = 0.0475 „ „ cane sugar (after inversion).
10 c.c. = 0.0801 „ „ maltose.

The difference between the cane sugar and glucose is here again explained by the fact that cane sugar produces on inversion more than its weight of glucose; 0.0475 gram of cane sugar yields 0.05 gram of glucose. Working with a 0.5 per cent. solution of cane sugar, each c.c. contains 0.005 gram, and 9.5 c.c. contain 0.0475 gram of sugar; 10 c.c. of the Fehling's solution should therefore require for its complete reduction 9.5 c.c. of the sugar solution.

As the Fehling's solution is rarely of the exact strength its equivalent in cane sugar must be noted so as to be used in each determination. Suppose the 10 c.c. of Fehling's solution required 9.3 c.c. of the sugar solution, then we know that 10 c.c. is equivalent to only 93/95 = 0.9789 of the respective quantities of different sugars given above. The exact strength of the Fehling's solution should be noted on the bottle, together with the date when the titration was made; the solution should be frequently tested against the solution of pure sugar. The quantity of sugar found must therefore be multiplied by 0.9789. An example will make this clear. A 0.5 per cent. solution of a commercial sugar was tested volumetrically, when 11.4 c.c. of the sugar solution were required to completely reduce 10 c.c. of the Fehling's solution. By titration 10 c.c. of the Fehling's solution are known to be equivalent to 0.9789 of 0.0475 = 0.0465 of pure cane sugar; that quantity is therefore present in 11.4 c.c. of the 0.5 per cent. solution. A 0.5 per cent. solution contains 0.005 gram of sugar, so that 11.4 c.c. contains 0.0570 gram of the sugar. As 0.0570 gram of the sample contains 0.0465 gram of sugar, the percentage of pure sugar in the specimen is 81.58. The analysis would appear in the notebook thus:—

"Volumetric determination of pure sugar in a commercial sample of cane sugar.

Inverted and made up to 0.5 per cent. solution.

11.4 c.c. required to reduce 10 c.c. of Fehling's solution, which = 0.0465 gram of pure cane sugar.

$$\frac{0.0465 \times 100}{11.4 \times 0.005} = 81.58 \text{ per cent. of pure sugar."}$$

686. Estimation of Maltose in Wheats or Flours.—The method of procedure is much the same as with cane sugar. The principal point is to obtain a solution of the right strength. Assuming that an aqueous infusion of wheat contains an average amount of 2.5 per cent. of maltose, then 100 c.c. of a 10 per cent. solution of the meal or flour contains 0.25 gram of maltose, so that 80 c.c. of the 10 per cent. solution are required in order to furnish an approximate amount of 0.2 gram of maltose. For each quantitative estimation, take 25 c.c. of Fehling's solution, 10 c.c. of water, and 80 c.c. of the clear 10 per cent. solution of the meal or flour. These quantities give the same degree of dilution as those directed to be used in the estimation of cane sugar; proceed exactly as in the determination of that substance. Having weighed the precipitate of Cu_2O, multiply by the factor 0.8077; the result is the quantity of maltose in 80 c.c. of a 10 per cent. solution of the meal or flour. As 80 c.c. of such a solution contain the soluble portion of 8 grams of the meal, the percentage is obtained by multiplying by 100/8 = 12.5.

In making this estimation the soluble proteins of the grain are kept in solution by the alkali of the Fehling's solution. They may, if wished, be removed by boiling and filtering the 10 per cent. solution. Put about 100 c.c. of the solution in a beaker, take the weight, and then boil for about five minutes; replace on the balance and make up to the original weight with distilled water. Filter off the coagulated proteins by passing the liquid through a dry filter; the filtrate is a 10 per cent. solution, *minus* the proteins coagulated by boiling.

If maltose is to be determined volumetrically, the solution should always be first freed from coagulable proteins in the manner just described. Take 10 c.c. of the mixed Fehling's solution, add 20 c.c. of water, and run in the clear 10 per cent. solution of the meal or flour until the reaction is complete, exactly as was done with the inverted cane sugar. The less quantity of water is added because of the maltose solution from the meal or flour being so very dilute.

In case the estimation of maltose is being made in a much stronger solution than that obtained by treating a meal with 10 times its weight of water, dilute the solution down until it contains approximately about one per cent. of maltose, and then work with exactly the same quantities as were directed for the inverted cane sugar 0.5 per cent. solution.

The estimation of maltose in wheats and flours is principally of value as a means of judging the amount of alteration which the starch has undergone; that a sugar analogous to cane sugar is also present is demonstrated by the experiment quoted in the early part of Par. 370, in which an additional precipitate is obtained as a result of treatment with hydrochloric acid. It must be remembered that with such an aqueous infusion there is always some change due to enzymic action on the starch of the wheat. If necessary, this action is obviated by destruction of the enzymes as a preliminary to the test. This may be done by boiling the flour with 95 per cent. by volume alcohol for one hour, filtering and air-drying.

687. Estimation of Dextrin.—Most substances which contain maltose contain also dextrin; thus the two are both found in wort produced from malt, and also in starch solutions that have been subjected to diastasis. Dextrin has no action (or but little) on Fehling's solution, but by prolonged treatment with an acid is converted into maltose, and ultimately into glucose. When maltose and dextrin are simultaneously present in a liquid, other carbohydrates being absent, the maltose is estimated in a portion as already described; another portion is treated with acid, by which both dextrin and maltose are converted into glucose. A second estimation of the copper oxide reducing power is then made. The weight of precipitate will be found to be considerably more than in the first estimation. This is due, in the first place, to the fact that glucose precipitates more Cu_2O than does maltose. The maltose originally present must be calculated into glucose, and the amount of precipitate due to it subtracted from the weight found in the second estimation: the remainder is reckoned as glucose produced by the hydrolysis of the dextrin; the percentage may be then obtained by calculation. Unfortunately, it is difficult to determine the exact point when the whole of the dextrin has been changed into glucose. When carefully worked the process is, however, sufficiently accurate for most technical purposes, and yields comparative results. The method is largely employed for the determination of dextrin in the worts made for malt assays. There follows a modification of the process adapted to the determination of dextrin in meals and flours. Having made a solution for the determination of maltose, take the same quantity of the solution as required for that estimation, viz., 80 c.c., and add to it 2 c.c. of dilute sulphuric acid (1 part concentrated acid to 8 of water), stand the mixture in a water bath, and heat to boiling for 4 hours. At the end of that time neutralise carefully with caustic potash solution (KHO), and proceed to estimate glucose by Fehling's solution precisely as before. The excess of glucose in the second solution over that produced by the maltose in the first requires to be calculated back to dextrin. It must be remembered that glucose is produced from dextrin according to the following equation:—

$$\underbrace{\underset{\text{Dextrin.}}{C_{12}H_{20}O_{10}} \quad + \quad \underset{\text{Water.}}{2H_2O}}_{\text{Molecular weight} = 324.} \quad = \quad \underbrace{\underset{\text{Glucose.}}{2C_6H_{12}O_6}}_{\text{Molecular weight} = 360.}$$

Therefore, every 360 parts of glucose thus produced represent 324 parts of dextrin in the original solution, or 10 of glucose = 9 parts of dextrin, so that glucose formed from dextrin × 9/10 = dextrin. As already stated, this method must only be looked on as giving results sufficiently accurate for technical purposes.

A useful alternative method of estimating dextrin depends on the fact that it is only very slightly soluble in alcohol of the strength of ordinary methylated spirits, whereas maltose, glucose, etc., are fairly soluble under the same conditions. The method is applicable to the soluble extracts of bread and flour, malt extracts, and similar preparations. When there are many such estimations to be made, a fairly large quantity of methylated spirits, say a gallon, should be redistilled (see paragraph 700), tested against purified dextrin, and reserved for this purpose. To purify dextrin, take some of the best light-coloured dextrin of commerce, and dissolve in water to about a 15 per cent. solution. Pour some of this, in small quantities at a time, in about a litre of redistilled spirit in a large flask, shaking vigorously between each addition. Dextrin will be precipitated, and should be finely divided, if in sticky clots the solution has been used too strong, and must be diluted. Filter off this precipitate, wash with alcohol, redissolve in water, and again precipitate with a large quantity of alcohol as before. Wash and carefully dry; the resultant purified dextrin should be colourless and tasteless (save for a slight flavour from the spirit). Dissolve 0.1 gram of the dextrin, and make up to 10 c.c. in water; add this quantity to 125 c.c. of the redistilled spirit, and shake well: there should be a slight precipitate. Filter and evaporate 50 c.c. to dryness in a weighed dish, and thus determine the amount of dextrin dissolved by the particular sample of spirit. Note same in calculated weight of dextrin held in solution per 270 c.c.

In making a determination, prepare, if possible, a solution of such a strength that 20 c.c. shall contain approximately 0.2 gram of dextrin. Add this to 250 c.c. of redistilled spirit in a flask, cork, and shake up: allow to stand a few hours, then pour off the clear, supernatant liquid on to a counterpoised filter, disturbing the precipitate as little as possible. Add 100 c.c. more of redistilled spirit to the precipitate, and shake vigorously, then transfer the dextrin to the filter, washing out the paper with the clear spirit filtrate; dry and weigh against the counterpoise, which must be washed successively with the first and second spirit filtrates. Add on to the weight thus found the 270 c.c. solubility correction. (The 100 c.c. of spirit used for washing does not redissolve any weighable quantity of the precipitated dextrin.) At times the dextrin precipitate sticks somewhat to the flask: in such cases rinse first with a little alcohol, and then dissolve out with a small quantity of water, and evaporate to dryness in a weighed dish. Add the quantity thus found to the total.

As in some cases the spirits may precipitate proteins as well as dextrin, it is advisable, where special accuracy is required, to make a nitrogen determination in the dry precipitate. For this purpose fold up the filter paper, and Kjeldahlise it together with the precipitate in the usual manner. Deduct the weight of protein from the total weight of precipitate.

Occasionally the proteins present will not separate, and produce an opalescent liquid which filters badly and extremely slowly. In this case make a fresh estimation, using stronger spirit, say 92-94 per cent., for precipitation. Let it stand at least 12 hours, or till clear, then wash the precipitate three times by decantation in the flask, shaking vigorously, and allowing to subside each time, using for this purpose *the weaker spirit.* Collect and weigh as before. In this case make a special test for the correction with some purified dextrin, operating in the same manner, and evaporating down known fractions of the lots of spirit used.

It should be added that alcohol precipitates in this manner not only dextrin, but also other gum-like bodies present, which are frequently returned in analysis as "indeterminate matters."

688. Polarimetric Estimations.—In addition to the method already described of estimating maltose and dextrin by means of Fehling's solution, there is a second process in which certain optical properties of these bodies are employed in the determination of dextrin, instead of hydrolysing that substance into glucose by means of dilute acid. This particular modification is of special value as a part of the process, to be hereafter described, of the estimation of starch, consequently it requires careful explanation.

As has been already stated, the sugars, in common with several other bodies, are capable of rotating the plane of polarisation of a ray of light. They possess this property not only in the solid state, but also when in solution; further, the amount of rotation is very nearly proportional to the degree of concentration of the solution.

689. Specific Rotatory Power.—The angular rotation of a ray of polarised light by a plate of any optically active substance, 1 decimetre (3.937 inches) in thickness, is termed its "specific rotatory power." In most substances this has to be obtained by calculation, because of the difficulty of getting transparent plates of a sufficient thickness. A solution of known strength is prepared, and from the rotatory power of this solution the specific rotatory power may be calculated. The rotatory power of solutions of the same strength may vary with the temperature, and also with the solvent employed, hence it is necessary to note the strength of the solution at the time of the estimation, and also the solvent used. The apparent or sensible specific rotatory power of a substance is found by dividing the angular rotation observed in the polarimeter (a) by the length of the tube in decimetres (l, usually $= 2$) in which the liquid is observed, and by the degree of concentration (c), that is the number of grams in 100 c.c. of the liquid. S being the specific rotatory power, then the above is represented by the formula—

$$S = \frac{a}{l \times \frac{c}{100}} = \frac{100a}{l \times c}$$

The rotatory power of a substance depends on the nature of the light used; as the instrument to be described is one in which the yellow monochromatic light of the sodium flame is employed, all numbers given will be for light of that description, which is often indicated by the symbol S_D.

In measuring rotatory powers of sugars it has been found convenient to take a plate of quartz, 1 millimetre in thickness, as the standard of comparison. According to the latest and most accurate measurements, such a plate produces an angular rotation of 21° 44′ = 21.73° for the sodium flame (S_D). The strength of the cane sugar solution which, in a tube 2 decimetres in length, shall exercise the same rotary power, is that equal to 16.350 grams of sugar in each 100 c.c. of the solution.

$$S_D = \frac{100 \times 21.73}{2 \times 16.350} = 66.45^\circ$$

as the specific rotatory power of cane sugar.

All sugars do not rotate the plane of polarisation in the same direction: thus, some twist it to the right, or in the direction of the hands of the clock, others twist it towards the left. The terms dextro- and lævo-rotation are applied to the right-handed and left-handed rotation respectively. Also the symbol + is used to represent dextro- and — to represent lævo-rotation. The specific rotatory power of substances varies somewhat with the degree of concentration of the solution. For a solution of approximately 10 per cent. strength, that of substances of importance in connection with the chemistry of wheat and flour is appended:—

Substance.	Formula.	Specific Rotatory Power.
Cane Sugar	$C_{12}H_{22}O_{11}$	$+$ 66.5°
Maltose	$C_{12}H_{22}O_{11}$	$+$ 138.3°
Glucose, Dextrose	$C_6H_{12}O_6$	$+$ 52.5°
Fructose, Lævulose	$C_6H_{12}O_6$	— 98° at 15° C.
Invert Sugar	$2C_6H_{12}O_6$	— 22.7° at 15° C.
Dextrin	$C_6H_{10}O_6$	$+$ 200.4°

690. The Polarimeter.—In order to measure the amount of rotatory power possessed by various bodies, an instrument known as a polarimeter is employed (sometimes spoken of incorrectly as a "polariscope"). There are various forms of this instrument, but one of the simplest is that known as the half-shadow polarimeter or "saccharimétre a pénombres." A well-known make of this instrument is illustrated in Fig. 87.

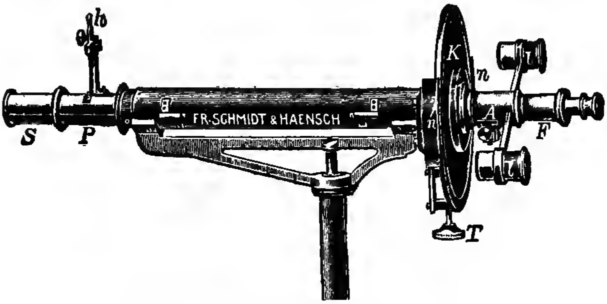


Fig. 87.—Half-Shadow Polarimeter and Vernier.

By means of a specially constructed bunsen lamp, a sodium flame is produced, and toward this the end, *S*, of the polarimeter is directed while employing the same. When using the polarimeter it is well to work in a room from which all light other than that of the sodium flame is excluded. The instrument consists essentially of a tripod support, carrying a horizontal frame, in which is placed the tube filled with the solution under examination, and having at the one end, *P*, the polarising prism, and at the other the analyser, *A*, together with a small magnifying arrangement used as an eyepiece, *F*. Immediately behind the analyser, *A*, is the disc, *K*, on which is engraved the scales of the instrument. Following this is the trough with hinged lid, in which are placed the tubes containing the liquid under examination.

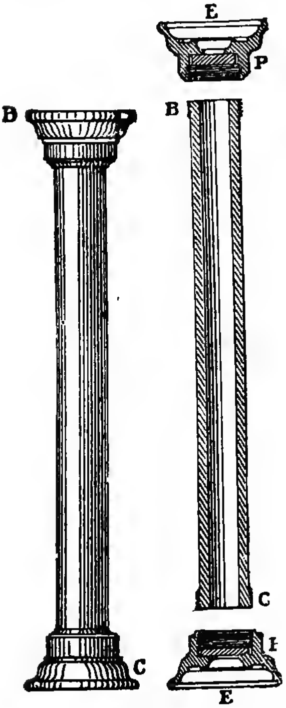


Fig. 88.—Polarimeter Tube.

691. Polarimeter Tubes.—These are now usually made of glass and are fitted at the ends with brass caps. Those most commonly used are exactly 20 centimetres in length from end to end inside the caps. The left-hand illustration, Fig. 88, represents the tube with the ends screwed on; the other shows the tube in section. Each cap contains a glass plate which fits accurately to the end of the tube; above the glass plate is a washer of leather; on screwing on the cap this washer exerts an equable pressure on the glass plate, and so makes a water-tight joint. The mistake must not be made of placing the washer inside instead of outside the glass plate. When using the tube, it is first cleaned, then dried, or rinsed with a few drops of the liquid under examination; one of the caps is next screwed on. The tube is then filled with the solution, any bubbles are allowed to escape, and then the second glass plate is slidden over the end and screwed tight by means of the cap. If properly filled, the tube should contain no air, neither should it leak. If there should be any tendency to leakage, it may be prevented by *very slightly* greasing the ends of the tube. It will be evident that such a tube contains a layer of the liquid exactly 20 centimetres in length.

692. Polarimeter Tube, with Thermometer.—Fig. 89 shows a polarimeter tube of slightly different construction: it is in the first place 22 instead of 20 centimetres long. On the top there is a tubulure, by which a thermometer is inserted in order to determine the temperature of the solution at the time the estimation is made. The use of this particular form of tube will be described hereafter.

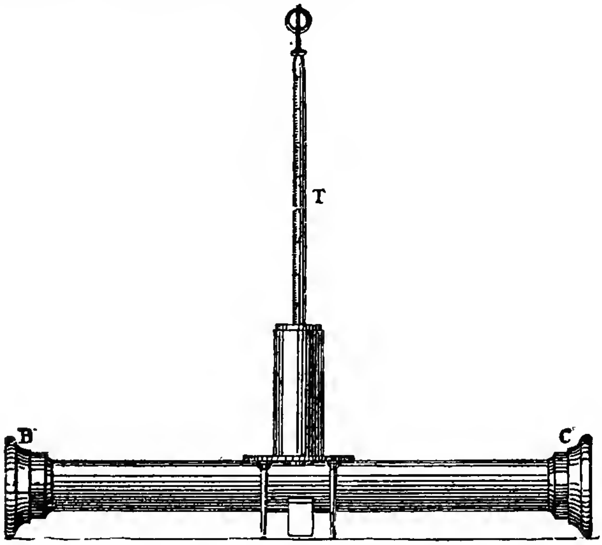


Fig. 89.—Polarimeter Tube, with Thermometer.

693. Verification of Zero of Polarimeter.—The first operation to be performed in starting work with a new polarimeter is to verify the zero of the graduated scale of the instrument. The commonest and most generally useful form is a scale graduated into angular degrees, namely, 90° to the right angle, or 360° to the whole circle. In addition to, or instead of, the angular scale, some instruments are provided with a sugar scale. This latter is a scale of 100 degrees, so arranged that when a specified quantity of cane sugar is taken, the number of degrees indicated by the polarimeter represents the percentage of pure sugar without any calculation. For present purposes, the angular scale only need be considered. On the dial of the instrument being described there is engraved a whole circle of 360° graduated into half-degrees, the zero being on the right-hand side, and the degrees reading upward and to the left, right round to 360. There are two fixed vernier scales, *n*, *n*, one on each side of the dial. Two magnifying glasses, *l*, *l*, are provided in order to read the scales. By means of the milled head, *T*, the dial may be readily rotated in either direction, together with the eye-piece and analysing prism. To make this verification of the zero, commence by placing some fused sodium chloride in the platinum spoon of the bunsen lamp, then light the bunsen, and turn the spoon into the flame, so that an intense yellow light is produced. Arrange the axis of the instrument in the direction of the flame, so that on looking through the eye-piece a brilliant yellow field is seen. Next fill one of the 20 centimetre tubes with distilled water, and put it in its proper position in the polarimeter. Place the zero of the vernier in coincidence with that of the scale, and look carefully through the instrument in order to see whether both halves of the field are equally illuminated. Turn the milled head, *T*, very slightly in either direction; one half of the field becomes dark, and the other lighter. Now focus the eye-piece, *F*, by drawing it out or pushing it in until the vertical line, dividing the two halves of the field, is sharply defined. Having focussed the eye-piece, turn *T* back again until the two halves of the field are equally illuminated: note the position of the vernier and see whether it coincides with the zero of the scale. (For reading the vernier use the eye-piece, *l*, drawing it in or out until the scale is sharply in focus.) Should the two agree, once more displace *T*, and again bring it back to the position in which the two halves of the field are equally bright, and read the vernier. Observe whether the two readings of the zero are alike. If the zero of the instrument is found correct, well and good, but if not, turn *T* until the zero of the vernier is exactly over that of the scale; then slacken the milled heads immediately underneath *A*, and screw in or out, until the two halves of the field are of the same depth of tint. Make this adjustment most carefully; when once made, re-tighten these milled heads until the tube *A* is securely fixed in the correct position. The instrument will then be permanently in adjustment.

The pointer, *h*, is used for the purpose of regulating the degree of sensitiveness of the instrument. The nearer the pointer is to zero the darker is the half-shadow side of the field for the same amount of angular displacement of the zero of the angular scale, and therefore the more sensitive is the reading. With absolutely transparent solutions, *h* may be fixed at zero, but with solutions that are not quite clear, the pointer must be moved slightly away from zero so that sufficient light may pass through. When *h* is moved, the zero of the dial plate must again be adjusted by means of the milled heads under *A*. Usually, when the instrument is received from the makers, *h* is arranged in the most convenient position for general work, and the zero of the instrument adjusted accordingly.

694. Method of Reading with Vernier.—To those not accustomed to the use of the vernier for the purpose of accurately reading graduations on instruments of exactitude, a few words of explanation of that device will be acceptable. The vernier is a small scale which slides over the graduations of the principal scale of the instrument. On the vernier a length, equal to 29 of the half-degree graduations on the fixed scale, is divided into 30 equal parts. As a consequence, each division on the vernier is exactly twenty-nine thirtieths of each on the fixed scale. Bearing this in mind, let us see how the vernier is used in actual work. Suppose that with the polarimeter a sugar solution is placed in the instrument, and the analyser turned until the two halves of the field are illuminated equally. It now becomes necessary to read off the number of degrees through which the analysing prism has been rotated. On looking at the scale, we find that the zero of the vernier is between, say 94 and 94.5 degrees. Look along the vernier scale in the direction of the 95 until one of the graduations on the vernier exactly coincides with one on the fixed scale. If this graduation on the vernier is 7 from the zero, then the accurate reading of the polarimeter is 94° 7′ (94 degrees 7 minutes, the minute being 1/30 of a half-degree, as there are 60 minutes to the degree). In fact, whatever number graduation on the vernier coincides with one on the other scale, the number of that particular vernier graduation represents the fraction of a half-degree in minutes. This will be seen to be the case on reflection. A fuller explanation of the vernier may be found in Ganot's or other work on "Physics."

In Fig. 87, the vernier scale is shown to the right of the illustration. In that particular instrument the main scale is divided into quarter-degrees and the vernier scale into 25 parts. Each graduation on the vernier scale is therefore equal to one twenty-fifth of a quarter-degree, or 0.01°.

695. **Polarimetric Estimation of Cane Sugar.**—As a matter of practice the student will do well to make some polarimetric estimations on pure cane sugar. For this purpose powder finely some clean coffee sugar crystals, and dry for a short time at 100° C. Make up respectively 10 and 20 per cent. solutions in distilled water, 100 c.c. of each. Fill a two-decimetre tube with the 10 per cent solution, which must be perfectly clear and transparent. Prepare the polarimeter for working and introduce the tube. By means of the milled head, rotate the analyser to the right until the point is attained at which the change from illumination of the one side of the field to that of the other occurs with great sharpness. Turn the milled head very slowly, and observe carefully the exact point at which equal illumination is reached. Read off the number of degrees by means of the vernier on the right-hand side of the instrument; then shift the analyser, once more bring it back to the neutral point, and again read. The two readings should agree to within 2 minutes (2′). If the sugar be absolutely pure, and the operation performed correctly, the reading should be precisely 13° 18′. This signifies that the sample under examination contains exactly 100 per cent. of pure cane sugar. Similarly, if the polarimeter stood at 12° 47′, we should state that the sample contained less than 100 per cent. of pure sugar.

As angular measurements are now frequently expressed in decimals of a degree instead of in minutes, the following table for the conversion of one into the other may be of service:—

Minutes =	decimals.	Minutes =	decimals.	Minutes =	decimals.
1	0.016	11	0.183	21	0.350
2	0.033	12	0.200	22	0.366
3	0.050	13	0.216	23	0.383
4	0.066	14	0.233	24	0.400
5	0.083	15	0.250	25	0.416
6	0.100	16	0.266	26	0.433
7	0.116	17	0.283	27	0.450
8	0.133	18	0.300	28	0.466
9	0.150	19	0.316	29	0.483
10	0.166	20	0.333	30	0.500

The figures 13°18′ and 12°47′ become 13.30° and 12.783° respectively. The percentage of pure sugar in the second case can readily be obtained by calculation:—

$$\frac{12.783 \times 100}{13.30} = 96.1 \text{ per cent.}$$

With the 20 per cent. solution the reading is practically double (subject to the fact that there is a very slight diminution of specific rotatory power with increase of concentration of cane sugar). If the sugar be pure the reading is 26°36′ or 26.6°, or with the same degree of impurity as before supposed, 12°47′ becomes 25°34′ or 25.566°.

696. Polarimetric Behaviour of Inverted Cane Sugar.—It has been already stated that the operation of treating cane sugar with an acid, and so causing it to precipitate cuprous oxide from Fehling's solution, is termed "inverting" the sample. The reason is, that a solution of sugar thus treated rotates the plane of polarisation to the left instead of to the right. Take a flask having two marks on the neck, one at 50 and the other at 55 c.c., fill up to the 50 c.c. mark with the sugar solution, and then add 5 c.c. of pure fuming hydrochloric acid. Next heat the flask in a water bath until its contents have acquired a temperature of 68° C.; this operation should be so arranged as to occupy about 10 minutes. Cool the flask by immersion in cold water. Fill the 22 centimetre tube with this solution, insert the thermometer, note the temperature and read the amount of rotation, which will be left-handed, with the polarimeter; that is to say, the dial must be turned toward the left instead of the right in order to reach the critical point of equal illumination. That having been done, the reading must be taken: in the instrument described, the point on the left hand of the dial, corresponding to zero, is 180 degrees, and the reckoning is usually taken from that point. Working with the 10 per cent. sugar solution, and assuming its purity, and that the thermometer registers 15° C. as the temperature of the solution, then the scale of the polarimeter read on the left-hand vernier stands at 175°28′. As 180 corresponds to zero, this amounts to the minus reading of 4°32′.

$$180^\circ - 175^\circ 28' = 4^\circ 32' = 4.533^\circ.$$

In order to distinguish them as left-handed readings, the minus sign is placed before the reading thus, $-4^\circ 32'$ or -4.533°. The reason for having a tube 22 centimetres in length will be evident; the addition of 5 c.c. of acid to 50 c.c. of sugar solution will have diluted the solution to 11/10 of its former volume. When the reading is taken in a 22 centimetre tube, that also is 11/10 of the length of the 20 centimetre tube, consequently a depth of liquid equal to 20 centimetres of the sugar solution before inversion is looked through. Working in this manner, no calculation is necessary for the dilution resulting from the addition of the acid. Careful observation has shown that a solution of cane sugar which before inversion had a right-handed specific rotatory power of $+66.5^\circ$, gives after that operation a rotation of 22.7° to the left, provided the temperature of the inverted solution is 15° C. Calculated in terms of specific rotatory power, the plane of polarisation is therefore, by the operation of inversion, rotated through 89.2°. As has been stated, inversion produces from the one molecule of cane sugar two molecules of glucose, one each of dextro-glucose and lævo-glucose. This latter body has a diminished rotatory power at high temperatures, and hence it becomes necessary to read the temperature at which the observation is made. At a temperature of 0° C. the range of inversion is 94.1°, and diminishes approximately by one angular degree for every three degrees rise in temperature, or 0.33 of an angular degree for each degree rise in temperature. This rate of diminution gives 89.2° for the temperature of 15° C. If possible the readings of the inverted sugar solution should be taken at 15° C., or failing that, at as nearly as possible that temperature. The correction per degree amounts to approximately $1/270 = 0.0037$ of the total range of inversion. Thus if the reading be taken at 18° C., the angular range will require to be increased by 3/270 of its total quantity.

A convenient way of expressing rotatory power is in that of "Rotatory power per gram in 100 c.c., the observations being made in a

2 decimetre tube." The figures thus obtained are one-fiftieth of the specific rotatory power, and are as follows:—

	Rotatory Power per Gram.
Cane Sugar	1.33°
Maltose	2.77°
Glucose, Dextrose	1.05°
Fructose, Lævulose	—1.96° at 15° C.
Invert Sugar	—0.45° at 15° C.
Change due to Inversion of Cane Sugar	1.78° at 15° C.
Dextrin	4.01°

Thus in the 10 per cent. pure sugar solution, the reading of 13.3°, on being divided by 1.33 gives 10, showing that there are present 10 grams of sugar in the 100 c.c. Similarly the amount of change as observed is

$$13.3 + 4.533 = 17.833.$$

On dividing this by 1.78, the result is again 10, confirming the previous determination of there being 10 grams of sugar present in the 100 c.c. In event of the sugar containing 10 per cent. of moisture, the right hand reading would only amount to 11.97° or 9/10 of 13.3°; similarly, the reading after inversion and calculation to 15° C. would amount to —4.08°. The amount of change would then be $11.97 + 4.08 = 16.05$. On dividing this as before by 1.78, the result is again 9, confirming the determination by direct reading on the unaltered sugar. If, on the other hand, some substance, as glucose, were present which is not capable of inversion by the method adopted, then the left-hand reading would be less than the theoretical amount for cane sugar. Thus the polarimeter affords not only a means of observing the percentage of sugar present in a sample, but also gives valuable indications as to the nature of the impurity.

In making polarimetric estimations of cane or other sugar or saccharine body, 20 grams may be taken and made up to 100 c.c. In the case of cane sugar, the polarimeter readings may be divided by the following factors $\frac{1.33}{5} = 0.266$ for direct reading, and $\frac{1.78}{5} = 0.356$ for amount of change due to inversion. The result is the percentage of sugar direct.

697. Polarimetric Determination of Dextrin and Maltose.—Attention must next be directed to the method of using the polarimeter for estimating the amount of dextrin in a liquid containing both dextrin and maltose. Should the liquid contain any coagulable proteins, they should first be removed by heating a known weight of the liquid for a few minutes in the hot-water bath, making up the lost weight with distilled water, and then filtering. It may happen that the liquid is not sufficiently clear to be transparent in a layer of so much as 20 centimetres; it may then be clarified by treatment with animal charcoal in the following manner:— Add to the solution, in a flask, about one-fifth of its volume of powdered, recently ignited, pure animal charcoal.[1] Shake up vigorously for a few minutes, and pass through a dry filter. Return the filtrate to the paper until it comes through perfectly clear. It is usually preferable, however, instead of treating with charcoal, to dilute the liquid with water, as charcoal apparently exercises an absorbent effect on some of the carbohydrates. Subject to this reservation, for the polarimetric reading, as concentrated a solution as possible should be taken, and the observation made

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[1] To prepare this, take 1 lb. of pulverised animal charcoal (bone charcoal) and boil with 2 quarts of commercial hydrochloric acid, diluted with 1 gallon of water. Filter through calico, and wash with water till free from acid, dry and ignite to redness in a closed crucible. Store in a well-stoppered bottle.

in the 20 centimetre tube. After reading with the polarimeter, dilute down to the right strength, and estimate maltose by Fehling's solution.

Knowing the quantity of maltose present, in order to calculate the proportion of the polarimetric effect due to dextrin, the amount of rotation due to maltose must be calculated. On multiplying the number of grams of maltose in 100 c.c. of the solution by 2.78, the result is the angular rotation due to the maltose. Subtract this number from the observed angular rotation, and the remainder is the angular rotation due to dextrin. This angular rotation, on being divided by 4.01, gives the grams of dextrin in 100 c.c. of the liquid. From these data the percentage of dextrin and maltose in the original substance may be calculated.

As an illustration of the polarimetric estimation of dextrin, the following example of the analysis of a sample of wheat germ is given. A 10 per cent. solution of the substance was made with cold water, filtered, shaken up with animal charcoal, and again filtered until clear. The clear solution was weighed in a beaker, raised to 100° C. in the water bath, made up to original weight, and filtered from the coagulated albumin. The reading with the polarimeter was 2.00° to the right. A maltose estimation was made with 20 c.c. of the solution to 25 c.c. Fehling's solution, and 50 c.c. of water. The resulting precipitate was in this instance converted by ignition into cupric oxide (CuO) and weighed as such, then—

Wt. of CuO, $0.1515 \times 0.7257 = 0.1099$ gram of maltose in 20 c.c. of 10 per cent. solution.

$0.1099 \times 5 = 0.5495$ gram of maltose in 100 c.c.

$0.5495 \times 10 = 5.495$ per cent. of maltose in the substance.

Then, $0.5495 \times 2.78 = 1.52 =$ angular rotation due to maltose.

Total angular rotation, $2 - 1.52 = 0.48 =$ angular rotation due to dextrin.

$$\frac{0.48}{4.01} = 0.12 \text{ gram of dextrin in 100 c.c.}$$

$0.12 \times 10 = 1.20$ per cent. of dextrin in the substance.

698. Estimation of Starch.—This estimation may be roughly made by retaining for examination the whole of the washings from the gluten test for wheat or flour. For this purpose wash the dough in small quantities of water at a time until the water remains clear, the washings being poured into a large beaker. Stir the starch and water thoroughly together, and then strain through a piece of fine silk into a second clean beaker, in order to recover any fragments of gluten that may possibly have been in the first instance forced through the silk. Having washed the whole of the starch through the silk, stand the beaker aside, in order to allow the starch to subside. Counterpoise a pair of filters and arrange them in funnels one under the other, so that the lower receives the filtrate of the upper. Remove the lower funnel and pour the supernatant liquid from the starch on to the upper filter; as soon as the filtrate runs clear, replace the second funnel and continue the filtration, finally rinsing the whole of the starch on to the filter; wash with distilled water and dry, first for a few hours at 40° C., and afterwards in the hot-water oven. The reason for first drying at a low temperature is to prevent the gelatinisation of the starch; this preliminary drying may generally be done on the top of the hot-water oven. The counterpoise filter may, of course, be dried direct in the oven, and at the end weighed against the starch and filter. The process of drying is much accelerated by giving the starch a final washing with 95 per cent. alcohol so as to remove the water. This treatment gives the weight of starch cells of the wheat or flour. These, it must be remembered, contain a certain quantity of starch cellulose.

699. Estimation of Soluble Starch by Conversion into Dextrin and Maltose.—For more refined estimations the method of first converting the starch into dextrin and maltose, and then determining those bodies, is preferable. O'Sullivan gives, in the *Journal of the Chemical Society* for the year 1884, a description in detail of his method of making such estimations. The method is based on first removing dextrin, maltose, and other soluble bodies from the substance by the use of water and other solvents, then converting the starch into dextrin and maltose by the action thereon of malt diastase, and then estimating the dextrin and maltose by Fehling's solution and the polarimeter. The following special reagents are necessary:—

700. Alcohol.—This reagent is required absolutely free from water and also mixed with water in different proportions. "Absolute" or water-free alcohol may either be purchased or prepared in the following manner:—Take two quarts of the best methylated spirits, add thereto about half its weight of recently and thoroughly burnt quicklime, shake up vigorously two or three times a day for 3 or 4 days. The quicklime will dehydrate the alcohol, by combining with the water present, to form slaked lime (calcium hydroxide). The alcohol must next be separated from the lime by distillation. For this purpose arrange a glass flask in a large saucepan to be used as a water bath. Fit a cork with leading tube to the neck of the flask, and connect this up to a condensing worm, provided with a copious supply of water. Be sure that all joints are perfectly air tight. Fill the water bath with water, and make arrangements for securing the flask, so that, as it becomes lighter by the evaporation of the spirit, it shall not capsize. Pour off the clear alcohol from the lime into the flask. Introduce a few small sharp-pointed steel tacks: these will cause the liquid to boil without bumping. Then connect up the whole of the apparatus, and raise the bath to the boiling point by means of a bunsen. Collect the distilled spirit in a dry stoppered bottle. It must be remembered that alcohol is highly inflammable, and therefore every care must be taken to prevent an accident through fire. The lime used for the desiccation of the alcohol will still contain a considerable quantity of spirit; this may in great part be recovered by pouring the whole on to stout calico and squeezing as much as possible of the spirit out.

Dry potassium carbonate is perhaps frequently a more convenient agent for desiccating alcohol. The carbonate absorbs the water, and forms a heavy solution on which the alcohol floats. When distilling, both solutions may be poured into the still together, and distillation in a water bath continued as long as anything comes over. The residual solution of potassium carbonate may then be evaporated to dryness in an ordinary iron saucepan, and used again for the same purpose.

Absolute alcohol has a specific gravity of 0.7937 at 15° C. The percentage of water is usually obtained by observing the specific gravity by means of a hydrometer. This is a glass instrument consisting of a weighted bulb and stem carrying a scale; the hydrometer, on being placed in a liquid, floats higher or lower according to its density. The specific gravity of water is often reckoned, for convenience, at 1000; absolute alcohol is then said to have a density of 793.7. A hydrometer should be procured from the instrument makers marked in single degrees from 750 to 1000.

Cool down some of the distilled alcohol to 15° C., and pour out into a hydrometer jar. (This is a tall glass vessel in which the instrument can just float.) Introduce the hydrometer, and observe the density of the liquid; should this be from 795 to 800, the alcohol may be considered for practical purposes absolute. Mixtures of alcohol and water of the following densities are also required:—820, 830, 860, 880, and 900 degrees. These may be prepared by adding water to methylated spirit.

Methylated spirit has itself a density of about 820, and, when redistilled, may be used when that strength is directed. The strength of solutions of other degrees of specific gravity is given below.

Specific Gravity, at 15.5° C.	Absolute Alcohol, by volume, %.	Specific Gravity, at 15.5° C.	Absolute Alcohol, by volume, %.
1.0000	0.00	0.8599	81.44
0.9499	41.37	0.8299	91.20
0.9198	57.06	0.8209	93.77
0.8999	65.85	0.7999	98.82
0.8799	73.97	0.7938	100.00

In order to obtain diluted spirits of the other gravities required, water may be added in the requisite proportion to methylated spirit. As alcohol and water, on being mixed, contract in volume (*i.e.*, 50 c.c. of alcohol and 50 c.c. of water produce less than 100 c.c. of the mixture), the amount of water to be added to the methylated spirit to produce each degree of dilution cannot be calculated with absolute exactness, but still sufficiently near for present purposes. Knowing that alcohol of sp. gr. of 820 contains 93.77 of alcohol and 6.23 of water, the quantity necessary to be added is determined by the following formula:—

A = percentage of absolute alcohol in stronger spirit.
a = ,, ,, ,, ,, weaker ,,
W = ,, water ,, stronger ,,
w = ,, ,, ,, weaker ,,
Q = quantity of water to be added to 100 c.c. of the lower sp. gr. spirit to produce the higher sp. gr. spirit.

Then
$$Q = \frac{A \times w}{a} - W.$$

From this formula it is found that to 100 c.c. of 820 spirit the following approximate quantities of water must be added to produce the spirits of correspondingly higher gravities:—sp. gr. 830, 3 c.c.; 870, 21 c.c.; 900, 43 c.c.

701. Diastase.—Take 2 or 3 kilograms (5 or 6 lbs.) of finely ground pale barley malt, add sufficient water to completely saturate it, and when saturated to slightly cover it. Allow this mixture to stand for 3 or 4 hours, and then squeeze as much as possible of the solution out by means of a filter press. Should the liquid not be bright, it must be filtered. To the clear bright solution, add alcohol of sp. gr. 830 as long as it forms a precipitate, and until the liquid becomes opalescent or milky. Wash this precipitate with alcohol of sp. gr. 860-880, and finally with absolute alcohol. Press the precipitate between folds of cloth, in order to dry it as much as possible. Then place the precipitate in a dish, and keep under the exhausted receiver of an air-pump, together with a vessel containing concentrated sulphuric acid, until the weight becomes constant. The kind of air-pump known as a mercury sprengel pump is best fitted for this purpose. Prepared and dried in this manner, diastase is a white, easily soluble powder, retaining its activity for a considerable time. Store the substance in a dry stoppered bottle, and keep in a cool and dry place.

702. Method of Performing Analysis.—The analytic operation is performed in the following manner:—Weigh out accurately 5 grams of the finely ground meal or flour; introduce this quantity into a wide-necked flask, with a capacity of 100 to 120 c.c. (a 4 ounce conical flask will be found most convenient). Add sufficient alcohol of sp. gr. 820 to just saturate the flour, and then 20 to 25 c.c. of ether. Cork the flask, and set aside for a few hours, shaking up occasionally. Decant the clear ethereal solution through a filter, wash the residue three or four times with fresh quantities of ether, pouring the washings each time on the filter. To the residue add 80 to 90 c.c. of alcohol of sp. gr. of 900; re-cork the flask, and maintain the mixture at a temperature of 35° to 38° C. for a few hours, shaking occasionally. When the alcohol solution has become clear, decant it through the filter used for filtering the ether solution, and wash the residue a few times with alcohol of the strength and temperature directed above. Wash the residue in the flask, and any that may be on the filter, into a beaker capable of holding 500 c.c., and nearly fill the beaker with water. In about 24 hours the supernatant liquid becomes clear, when gradually decant through a filter. Wash the residue repeatedly with water at 35° to 38° C., and then transfer to 100 c.c. beaker. Take the filter from the funnel, open out the paper on a glass plate, and remove every particle by means of a camel-hair brush cut short, and a fine-spouted wash-bottle. Having thus transferred the whole of the residue, the beaker should not contain more than 40 to 45 c.c. of liquid. Boil for a few minutes in the water bath, care being taken to stir well in order to prevent "balling," or unequal gelatinisation of the starch. After this, cool down the beaker still in the bath to 62° to 63° C., and add 0.025 to 0.035 gram of diastase dissolved in a few c.c. of water. In a few minutes the whole of the starch is dissolved, and a trace of the liquid gives no discolouration with iodine. Continue the digestion for about an hour, then raise the bath to the boiling point, and boil for 8 or 10 minutes. Pour the contents on to a filter, and receive the filtrate into a 100 c.c. measuring flask; carefully wash the residue with small quantities at a time of boiling water. Cool the flask to 15.5° C., and make up its contents to 100 c.c. with distilled water. Should the washings and solution exceed 100 c.c., they must be evaporated down to that amount.

Take a polarimetric reading of this solution in the 20 centimetre tube. Five c.c. of the solution is a convenient quantity to take for the estimation of maltose. This is rather a small quantity to measure accurately; it may, if wished, be weighed instead, or 25 c.c. may be taken and diluted down to 100 c.c. with water; 20 c.c. of the diluted solution may then be taken and added to 25 c.c. of Fehling's solution and 50 c.c. of water. Proceed as before described with the estimations, and calculate the quantity of maltose from the weight of precipitated Cu_2O. Calculate the relative percentages of dextrin and maltose in the usual manner. Starch produces its own weight of dextrin and $342/324 = 1.0546$ its weight of maltose. To obtain the weight of starch from the dextrin and maltose it produces, the weight of the dextrin must be added to that of the maltose divided by 1.0526, or multiplied by 0.95. These calculations will be rendered clear by the study of the following example taken from O'Sullivan's paper.

In the analysis of a sample of white wheat, 4.94 grams were taken. The 100 c.c. solution had an optical activity equivalent to 8.52° for S_D, and contained 2.196 grams of maltose.

$2.196 \times 2.78 = 6.10°$, angular rotation due to maltose. $8.52° - 6.10° = 2.42°$, angular rotation due to dextrin. $2.42/4.008 = 0.605$ gram of dextrin in 100 c.c.

Maltose, 2.196 = starch, $2.196 \times 0.95 = 2.086$
Dextrin, 0.605 = starch, 0.605

Total starch = 2.691

$$\frac{2.691 \times 100}{4.94} = 54.47 \text{ per cent. of starch present.}$$

A duplicate analysis on 6.009 grams differed only by 0.03 per cent.

In the absence of diastase, starch may usually be determined with sufficient accuracy for technical purposes in the following manner:—Remove by washing or otherwise all other carbohydrates, and gelatinise the starch by heating with water. From a known weight of the same variety of starch prepare a solution of approximately the same strength. Put 50 c.c. of each in a separate flask, and add 50 c.c. of 10 per cent. sulphuric acid. Cork the two flasks, and stand in a hot-water bath until a drop on being taken out gives no reaction with iodine solution. Then neutralise by adding solid caustic potash in small fragments, until the solution gives a faintly alkaline reaction to litmus paper; and precipitate from 10 to 25 c.c. of the solution, according to strength, with Fehling's solution. Knowing by the test with pure starch what weight of Cu_2O it precipitates under these conditions, the quantity of starch in the substance being tested can be readily calculated.

703. Estimation of Dextrin and Soluble Starch.—It occasionally becomes necessary to estimate dextrin in the presence of soluble starch, as, for instance, in bread soluble extracts. The following method may then be adopted:—Take 20 c.c. of the soluble extract and add to 250 c.c. of redistilled spirits; if the precipitate is very little, take double the quantities; filter and proceed with the estimation precisely as previously directed for dextrin. Control the results by determining proteins in the dried and weighed precipitate—the residue is a mixture of dextrin and starch.

Proceed to estimate the starch in the following manner:—Prepare first of all the following reagents—

0.5 per cent. solution of wheat starch.
5 per cent. solution of sulphuric acid.
Solution of iodine in potassium iodide of sherry tint.

Take two graduated Nessler glasses, and add to each 0.1 c.c. each of iodine solution and sulphuric acid; make up to 50 c.c. with distilled water. To one add 0.5 c.c. of starch solution and stir; to the other add the diluted soluble extract from a burette until there is the same depth of blue tint in each. The solution to be tested is conveniently of approximately the same strength as the standard starch solution. If this first test shows it to be too concentrated, dilute, and repeat the estimation. Having read off the solution necessary to match the 0.5 c.c. of standard starch, add another 0.5 c.c. to the standard in the Nessler glass, and again run in the extract solution until the colours are of equal depth of tint. Take the reading, and add another 0.5 c.c., and repeat the titration. In this way three separate readings are obtained, which should closely agree. The following are results obtained in an actual analysis:—

Standard Starch Solution.	Diluted Bread Extract.
0.5 c.c.	0.30 c.c.
1.0 „	0.55 „
1.5 „	0.85 „
3.0 „	1.50 „

The whole of these come very closely together, and it was assumed that 1.5 c.c. of the bread extract contained as much starch as 3.0 c.c. of the standard starch solution.

To ensure success with this method of starch estimation the solutions must be dilute, and there should be no other colour-producing body than starch present. The iodine must not be in a large excess, but must give a pure blue colour with starch: too much produces a dirty greenish blue. But the iodine must be in excess of the starch present. To ascertain this by trial, after a titration, add a few drops more starch and the colour should darken. Both tests must be made up with precisely the same quantity of each reagent.

Having determined the starch in this manner, deduct the amount from the total of starch and dextrin precipitated by alcohol; the difference is dextrin.

704. Estimation of Cellulose.—The student already knows that cellulose has the same chemical composition as starch, but that it differs from that body in being insoluble in boiling water. The cellulose or woody fibre of grain has been estimated at about 10 per cent. of the whole: but of this much is soluble in the digestive secretions of animals, particularly those which ruminate, therefore an estimation of cellulose simply is not the one most valuable to the chemist whose investigation is made for the purpose of determining the food value of a substance. What for this purpose should be ascertained is that percentage of the grain or flour which is ejected from the alimentary canal in an unaltered condition. A process is therefore selected which is somewhat similar to the digestive action which proceeds in the stomach, this action being imitated by alternate treatment with dilute acid and alkali.

705. Special Reagents Necessary.—The first of these is a 5 per cent. solution of sulphuric acid. In a small beaker weigh out 100 grams of the concentrated acid, and make up to 2 litres. In the next place prepare a 12 per cent. solution of caustic potash by weighing out 240 grams of the pure dry sticks, dissolving, and making up to 2 litres with water. It is important that 20 c.c. of the acid solution should be approximately neutralised by 10 c.c. of the alkali.

706. Mode of Analysis.—Take 5 grams of the meal or flour, and mix them thoroughly with 150 c.c. of water in a beaker. Stand this in a hot-water bath, and raise to a boiling heat in order to effect the gelatinisation of the starch; stir frequently with a glass rod; add 50 c.c. of a 5 per cent. solution of sulphuric acid, and continue the boiling for an hour, stirring occasionally, and maintaining the volume at 200 c.c. by adding from time to time a little water. (The proper volume should be indicated by a mark made with the diamond on the outside of the beaker.) The acid will by this time have converted the starch into sugar. To this solution next add 50 c.c. of the solution of caustic potash; this quantity will neutralise the free acid, forming potassium sulphate, and will leave an excess of alkali in the solution approximately equivalent to the amount of acid first used. Again boil in hot-water bath for an hour, adding water to supply that lost by evaporation, and occasionally stirring. At the end of this time, dilute with cold water, stir, and allow the residue to subside. Wash by decantation, using large quantities of tap water (provided it is absolutely free from sediment), pouring as little as possible of the residue on to the paper. Stout, well-made quantitative filters of about 8 or 10 inches diameter should be employed. Next transfer the residue to the filter, and wash once with dilute hydrochloric acid, in order to dissolve any calcium carbonate that may be precipitated from ordinary water by the potash. Then wash with distilled water till free from acid, and allow the filter to drain. While still wet, remove the filter paper from the funnel, carefully spread it out flat on a sheet of glass, and with a wash bottle and short camel-hair brush, transfer the whole of the residue to a counterpoised glass dish; dry in the hot-water oven and weigh. The dry residue multiplied by 20 gives the percentage of indigestible fibre in the sample.

ANALYSIS OF BODIES CONTAINING CARBOHYDRATES.

707. Malt.—It is comparatively rarely that for bakers' purposes an analysis or assay of malt is required. The principal point is the character and amount of extract it affords on being mashed; to this reference has already been made in Chapter XII., paragraph 396. A miniature mash of the same proportions may be made in the following manner:—Finely grind the sample of malt, mix thoroughly, and weigh out 158 grams; mix with about 900 c.c. of warm water, and place in a water bath maintained at a temperature of 60° C. Let it remain until a drop taken out after stirring gives no starch or amylodextrin reaction with iodine. Then raise to the boiling point, cool, and transfer the whole to a litre flask; make up to the mark with distilled water; pour out into a larger flask or beaker, and add another 50 c.c. of water. Thoroughly mix, allow to settle, and take the density of the supernatant liquid, at a temperature of 15.5° C., by means of the hydrometer. The quantities taken are equivalent to 40 gallons of wort from 63 lbs. of malt: the extra 50 c.c. are allowed in order to provide for the average amount of "grains" resulting from this quantity of malt. There are thus 1000 c.c. of wort from 158 grams of malt. The percentage of solid extract yielded by the malt is readily calculated. Thus, supposing in a test the hydrometer density is 1035, then:—

$$\frac{(1035 - 1000) \times 10}{3.85} = 90.9 \text{ grams of solid extract in 1000 c.c. of wort.}$$

$$\text{As } 158 : 100 :: 90.9 = 57.53 \text{ per cent. of solid extract.}$$

The whole of the constants in the above may be reduced by one single factor, 1.644, and we then have

$$(1035 - 1000) \times 1.644 = 57.54 \text{ per cent. of solid extract.}$$

For a detailed description of the method for an exhaustive assay of malt, the reader is referred to Moritz and Morris' *Science of Brewing*, pages 452 *et seq.*

708. Malt Extracts.—The following determinations should be made in analysing extracts of malt and similar preparations:—Reducing sugars, cane sugar, dextrin, proteins, water, phosphoric acid (P_2O_5), other mineral matter, specific rotatory power, and diastatic capacity by Lintner, or other methods hereinafter described. A 10 per cent. solution of the substance should first be prepared, which, either with or without dilution, may be employed for the following estimations.

Reducing Sugars.—Take 2 c.c. of 10 per cent. solution, and precipitate as usual with Fehling's solution (30 c.c.).

Cane Sugar.—This is conveniently determined by O'Sullivan's method. Take 20 c.c. of 10 per cent. solution, make up to 100 c.c., raise to 55° C., and add 0.2 gram of solid brewers' yeast (prepared by drying the liquid yeast on a towel), or compressed distillers' yeast free from starch, digest in a constant temperature water bath at 55° C. for 4 hours, make up loss by evaporation (or conduct the operation in a tightly corked flask), filter, and determine reducing sugars in 10 c.c. by Fehling's solution. The difference in weight of Cu_2O obtained in this and the preceding determination is Cu_2O reduced by the glucose from cane sugar, and is readily calculated into the percentage of that body.

Dextrin.—Take 20 c.c. of 5 per cent. solution, add to 250 c.c. of spirit, and proceed as described under Estimation of Dextrin, paragraph 687. Should the amount of precipitate be very small, recommence the estimation, using the 10 per cent. solution. Determine proteins by Kjeldahl's process in the dried and weighed precipitate; deduct from the weight of precipitate, and calculate as dextrin.

Proteins.—Determine direct by Kjeldahl's process on 1.0 gram of the extract.

Water.—Take 5 grams of extract, dry till weight is constant in a platinum basin; about 36 hours are necessary at 100° C. When speed is an object, either a smaller quantity (1.0 gram) may be used, or an oven at 110° C. employed. Or preferably a vacuum drying oven may be used, in which case the drying may be conducted at a temperature below 100° C.

Ash.—Ignite the dried residue from 5.0 grams (residuum from water estimation) until a white ash is obtained. Note, the extract sometimes swells up enormously as it carbonises; in such cases allow to cool, and break down the carbonaceous mass so that it lies easily in the dish. (This should be done on a sheet of glazed paper.)

Phosphoric Acid.—Dissolve the ash in dilute nitric acid (1 to 3), and proceed with estimation by molybdate and "magnesia mixture" (see paragraph 653). The ash, less phosphoric acid, gives "other mineral matter."

Specific Rotatory Power.—Make up a 20 per cent. solution of the extract, and take a polarimetric reading precisely as described in paragraph 697 on Polarimetric Determination of Dextrin and Maltose. Calculate out the specific rotatory power both on the whole and the dried extract: or, if preferred, the rotatory power per gram of either whole or dried extract may be calculated. For the whole extract, with a 20 per cent. solution, this is 1/20 of the total angular rotation. Supposing in the case of an extract the total solid matter to be 80 per cent., and the observed rotation 32.4°, then

$$\frac{32.4}{20} = 1.62^\circ \text{ rotatory power per gram of whole extract;}$$

$$\text{and } \frac{100 \times 1.62}{80} = 2.02^\circ \text{ rotatory power per gram of dried extract.}$$

The specific rotatory power may be obtained by multiplying by 50 in each case.

Calculation of Results.—The reducing sugar of pure malt extracts, obtained by concentrating the wort produced by total conversion of the whole malt, consists principally of maltose. On calculating it as such, and adding together the results of the whole of the determinations given, there is usually an excess of about 5, or more, per cent. over 100: this is due to some of the reducing sugar being glucose instead of maltose. On the other hand, cold water extracts of malt contain only the pre-existent sugars of malt, considerable proportions of which are glucose: these, if worked out as maltose, give far too high a result, while if calculated as glucose, the result is too low. Again the explanation is that in addition to glucoses there is maltose also present. It is frequently convenient to be able to estimate approximately the relative proportions of glucoses and maltose, and this may be done in the manner to be now described. It should first, however, be mentioned that doubtless malt extracts contain certain substances which escape determination in all the estimations previously given; but these cannot in any case represent a large percentage of the whole, and for present purposes may be neglected, the reservation being made that a small part of the percentage returned as sugar may consist of indeterminate bodies. Assuming that 100, less the cane sugar, dextrin, proteins, water, and ash, consists of reducing sugars, then we have

Total reducing sugar by difference in 100 grams extract $= S$.
Weight of cuprous oxide precipitated by 100 grams extract $= W$.
,, maltose in 100 grams $= m$.
,, glucose ,, $= g$.
,, cuprous oxide precipitated by 1 gram of maltose $= 1.238$ grams.
,, cuprous oxide precipitated by 1 gram of glucose $= 1.983$ grams.

$$\text{Then, } m + g = S: \quad \text{(Equation No. 1.)}$$

$$\text{and } 1.238\, m + 1.983\, g = W. \quad \text{(Equation No. 2.)}$$

From these the values of m and g may be determined thus:—

Multiplying equation No. 1 by 1.983, and subtracting No. 2 from the product, we get

$$\begin{array}{rl} 1.983\ m + 1.983\ g & = 1.983\ S \\ \text{Less } 1.238\ m + 1.983\ g & = W \\ 0.745\ m \qquad\qquad & = 1.983\ S - W \\ \text{and } m \qquad\qquad & = \dfrac{1.983\ S - W}{0.745.} \end{array}$$

$$\text{In the same way } g = \frac{W - 1.238\ S}{0.745}$$

$$\text{or more simply, } g = S - m.$$

The following figures were obtained in the analysis of a sample of malt extract:—

$$S = 60.5. \qquad W = 80.$$

$$m = \frac{(1.983 \times 60.5) - 80}{0.745} = 53.65.$$

$$S - m = g, \text{ therefore } 60.5 - 53.65 = 6.85.$$

The percentages of maltose and glucose are therefore respectively 53.65 and 6.85.

In pure malt extracts obtained by concentration of the wort of the entire malt, so mashed as to ensure the hydrolysis of the whole of the starch, the percentage of glucose should not exceed from 1/7 to 1/8 that of maltose. With highly diastatic extracts containing also a high percentage of proteins, the proportion of glucose is as a rule considerably greater. On comparing the results thus obtained with the specific rotatory power of the sample, it will be found that the glucose is almost entirely of the dextrose or right-handed variety.

The other calculations require no detailed explanation.

709. Diastatic Capacity on Lintner's Scale.—For brewing purposes diastatic capacity is now almost invariably determined by Lintner's method and the result expressed on Lintner's standard, or in "degrees

Lintner.'' That standard is:—''The diastatic capacity of a malt is to be regarded as 100, when 0.1 c.c. of a 5 per cent. solution reduces 5 c.c. of Fehling's solution.''

For the determination, ''soluble starch'' and standard Fehling's solution are required. The soluble starch must be prepared according to the method described in Chapter VI., par. 173. The digestion with acid must be allowed to proceed fully as long as directed, as, unless the starch is rendered thoroughly soluble, it naturally gives apparently low diastatic results. It is well during its preparation to test a small portion at the end of 7 days by thoroughly washing, and then dissolving in boiling water: the solution must be absolutely clear and limpid. When about to make an estimation, take 2.2 grams of the soluble starch and dissolve in hot water, cool, and make up to 110 c.c. If testing a malt or flour, take 25 grams (of course, finely ground) and digest with 500 c.c. at ordinary temperatures for 5 hours. Filter until perfectly bright. Arrange ten test tubes in a stand, and add to each 10 c.c. of the soluble starch solution. Then to the first, add 0.1 c.c. of the malt or flour filtrate, to the second 0.2 c.c., and so on until the last receives 1.0 c.c. Shake them thoroughly, and allow the whole to stand for 1 hour in a water bath maintained at the constant temperature of 70° F. During this time the diastase will have converted more or less starch, according to its strength. Next add 5 c.c. of Fehling's solution to each of the tubes, shake up, and place the whole series in boiling water for 10 minutes. Allow the precipitate to subside, and note the condition of the tubes; in some the blue colour will probably have entirely disappeared, showing them to be over reduced, while others will still be more or less blue. Select the two tubes lying together in which one is slightly over and the other slightly under reduced. The number of c.c. required to give exact reduction will lie between these, and should be judged according to which it appears the nearest. Thus, suppose as nearly as possible it is exactly midway between Nos. 5 and 6, then the quantity of malt solution may be taken as 0.55; while if No. 5 is full yellow, while No. 6 is only very faintly blue, then one would give the quantity as 0.58 or 0.59, according to how near in one's judgment it appeared to be to the 0.6. With a little practice one soon gets able to judge very closely this second decimal. If the result of a test gives 0.5 c.c. as the quantity of malt solution required, then the sample is evidently only one-fifth of the standard strength of 100, or

$$\frac{0.1 \times 100}{0.50} = 20^\circ \text{ Lintner as diastatic capacity.}$$

But there is a certain amount of reducing sugar extracted from malt by cold water, and this also helps to reduce the Fehling's solution. The amount of this is determined in the following manner:—Take 5 c.c. of Fehling's solution, 10 c.c. of starch solution, and 10 c.c. of water, and raise to the boiling point in a small flask. To this add the malt solution from a burette until the Fehling is exactly reduced; then determine the apparent diastatic capacity of this solution. Supposing that 7 c.c. have been run in in order to reduce the Fehling, then

$\frac{0.1 \times 100}{7} = 1.43^\circ$, correction for reducing sugars extracted from the malt.

For malts the correction 1.4 may usually be taken as a constant, and the above results become

$$20 - 1.4 = 18.6^\circ \text{ Lintner.}$$

Working with malt extracts, the value of the correction becomes much higher, and must be determined for each individual sample analysed, and preferably *before* the diastase estimation. Take a 5 per cent. solution of the extract, boil, make up to original volume, filter, and titrate on Fehling and starch as above described. In an actual analysis 1.25 c.c. of the 5 per cent. solution were required; the correction therefore becomes

$$\frac{0.1 \times 100}{1.25} = 8.0^\circ \text{ correction for reducing sugars present.}$$

From this it will be seen that the tenth tube in the diastase determination is nearly reduced by the sugars present alone. The diastase estimation should now be made: this in the sample in question amounted to 0.73 c.c.; then

$$\frac{0.1 \times 100}{0.73} = 13.7^\circ \text{ apparent diastatic capacity.}$$

$$13.7 - 8.0 = 5.7^\circ \text{ Lintner, real diastatic capacity.}$$

In malt extracts and other diastatic preparations the diastatic capacity varies very widely, and either none or all of the series may be completely reduced. In the former case the diastatic capacity must be less than 10 *minus* the correction. Make another diastase estimation with a 25 per cent. solution of the extract, and multiply the correction by 5; the solution being of 5 times strength, the net figure thus obtained for real diastatic capacity must be divided by 5 in order to give degrees Lintner. Should there be no reduction in any of the tubes, the diastatic capacity must be less than 2 *minus* the correction, which practically amounts to its total absence.

On the other hand, the whole of the series may be reduced, showing that the diastatic capacity is more than 100 *minus* the correction. In this case make up a 0.625 per cent. solution, and use it for a diastase estimation; multiply the result by 8, and take the correction as 1/8 that with the 5 per cent. solution. The following is the result of an estimation on a diastase preparation made by the authors:—

Correction for reducing sugars on 5 per cent. solution = 8.2°.

All tubes were reduced.

With 0.625 per cent. solution, reduction effected by 0.42 c.c.

$$\frac{0.1 \times 8 \times 100}{0.42} = 190.5^\circ \text{ apparent diastatic capacity.}$$

$$190.5 - \left\{ \frac{8.2}{8} = \right\} 1.02 = 189.48^\circ \text{ Lintner, real diastatic capacity.}$$

The three diastase tests made in this manner give a total range of from 2° to 800° Lintner, and with each test overlapping the other.

In comparing extracts for bread-making purposes, it is sometimes advisable to also test on starch paste; in that case proceed exactly as with soluble starch, except that ordinary starch is substituted and carefully gelatinised without "balling."

710. Diastase Tests on Flours.—These may be made by taking a given quantity of the extract, mixing with flour and water, and digesting for a given time at some fixed temperature. The amount of matter dissolved and maltose produced may then be determined by direct estimations. Full particulars of such determinations follow.

A 0.5 per cent. solution is prepared of the extract. Of this, 100 c.c. (= 0.5 gram extract) is taken, added to 25 grams of flour in a corked flask, shaken vigorously, and digested for 4 hours in a water bath at 140-150° F. A blank experiment is also made with 100 c.c. water and 25 grams of flour only. The contents of the flasks are filtered, and "soluble extract" and maltose determined in the clear filtrate.

Baking tests afford the most valuable means of testing diastatic value of extracts for bakers. These tests should be made as directed in Chapter XXI., paragraph 644, with the extract added to the water. It is well to take the uniform quantity of the extract equivalent to 1 lb. to the sack, 2 grams = 20 c.c. of a 10 per cent. solution (the quantity of water used for dough-making must, of course, be diminished by the 20 c.c. taken with the extract). Prepare 100 c.c. of the 10 per cent. solution, place half of it in a flask, weigh, boil for 5 minutes, and make up to the original weight with water, and call this No. 2. Prepare duplicate loaves, using the No. 1 or unheated extract solution in the first, and No. 2 or boiled solution in the second. Make up also a plain loaf, No. 3, with the same flour; compare carefully the character of the three for volume, colour, pile, moistness, flavour, and any other points of interest to the baker. No. 2 will have had its diastase killed, and will contain only such maltose and other bodies as are contained in the extract; No. 1 will contain in addition all such substances as have been produced by the diastatic action of the extract itself.

If wished, determinations may be made of soluble extract and maltose in each of the loaves. The results may then be returnd as shown in blank below:—

	Soluble Extract.	Maltose.
Normal Quantities in Plain Bread, *determined in No.* 3	......	......
Quantities added in Extract, *being difference between Nos.* 2 *and* 3	......	......
Quantities produced by Diastatic Action, *being difference between Nos.* 1 *and* 2..	......	......
Total	......	......

In this way any extract can at once be valued both for added and produced maltose and other substances.

711. Adulterations of Malt Extract.—Malt extract may be adulterated either with molasses (treacle) or glucose syrups. The former of these may be detected by the large increase in the quantity of cane sugar present, as molasses contains from 35 to 48 per cent. of sucrose. It also usually contains considerable amounts of glucose. The so-called sirupy "glucoses" contain, when conversion has been arrested at the minimum point, large quantities of dextrin and maltose, and therefore in that particular closely resemble malt extracts. Commercial "glucose" is, however, practically devoid of protein constituents, and in this way is detected when used as an adulterant of malt extract. A polarimetric reading affords a valuable indication as to the purity of malt extracts. The following table gives the result of a number of such readings calculated to angular rotation per gram of undried substance in 100 c.c., the observations being made in a 2 decimetre tube.

POLARIMETRIC ESTIMATIONS ON MALT EXTRACT, ETC.

No.			Rotatory Power per Gram.
1.	Malt Extract of known purity, tested March, 1893		1.59°
2.	Same make of Extract, sample taken April, 1893		1.52°
3.	Sample of suspected Malt Extract, very light in colour		1.99°
4.	Second sample of suspected Malt Extract		1.79°
5.	Lyle's Golden Syrup, obtained personally by author		0.52°
6.	No. 1 Syrup, lightest colour	From same manufacturers	1.05°
7.	No. 2 „ intermediate		0.81°
8.	No. 3 „ darkest		0.52°
9.	"Glucose" Syrup (White Confectioners')		2.30°
10.	Mixture made personally by authors—		
	No. 1, 7.07 grams No. 6, 4.79 „		1.33°
	Calculated Rotatory Power from quantities taken		1.33°
11.	Mixture made personally by authors—		
	No. 1, 7.07 grams No. 9, 6.26 „		1.85°
	Calculated Rotatory Power from quantities taken		1.89°

Both the suspected samples had abnormally high rotatory powers, and were probably adulterated with "glucose" syrup; they agree approximately with No. 11. For comparison with the rotatory powers of the pure substances refer to paragraph 695.

CHAPTER XXV.

BREAD ANALYSIS.

712. Principles of Bread Analysis.—Having described the methods to be employed for the determination of the various constituents of wheat and flour, a short description must now be given of bread analysis.

Many of the properties by which good bread is distinguished from bad scarcely come within the range of purely chemical analysis. Among these are the colour, texture, ''piling,'' odour and flavour of the crumb, and the colour and thickness of the crust. In the kind of bread known technically as ''crumby'' bread, the colour and texture of the joint between two loaves is to be observed. The analyst, in reporting on bread, should examine the loaf so far as the above characteristics are concerned, and include his opinion on the same in his report. In judging each, he may adopt the plan of employing a series of numbers, say 1 to 10, and using the lowest number for the worst possible grade, and the highest for the very best. Or he may use instead the terms V. B., very bad; B, bad; I, indifferent; M, moderate; G, good; V. G., very good; E, excellent. In either case the same term must, so far as is possible, be applied to the same grade of quality, whether of texture, colour, or other characteristic.

713. Colour.—The baker's use of this term involves a contradiction; it is the custom of the trade to speak of a loaf as ''having no colour'' when a dark brown, while in the purest white loaf the colour is said to be ''high.'' This is, of course, exactly opposite to the correct use of these terms, for white is strictly no colour, while a yellow or brown body is strongly coloured. It would be a better plan if the respective terms were ''lightly coloured'' and ''strongly or deeply coloured.'' Judging colour by itself alone, the loaf should be a very light yellow or creamy tint, approaching almost to whiteness. This colour is selected because the authors are of opinion that, judging bread by the eye alone, the slightest yellow hue is more agreeable than an absolute snowy whiteness. The latter, perhaps from its frequent association with absence of flavour, is unpleasant.

It must be remembered that colour, etc., are matters of individual taste and opinion, and therefore that each individual has his own standard of comparison. In forming a judgment one naturally most appreciates that in accordance with one's own standard; it does not necessarily follow that such judgment shall absolutely agree with that of another person. It is a well-known fact that in different localities the standard of taste in these matters varies.

For actual measurement of bread colour, the method of testing with the tintometer should be employed; or baked loaves may be compared against those similarly prepared from standard samples of flour.

714. Texture.—The texture of a loaf is best observed by cutting it in two with a very sharp knife. There should be an absence of large cavities, and also of dry lumps of flour. The honeycombed structure of the bread should be as even as possible. The bread should not break away easily in crumbs, but should be somewhat firm. On being gently pressed with the finger the bread should be elastic, and should spring back without showing a mark on the pressure being removed.

715. Proof.—Like many other trade terms, this is used in a somewhat different sense in different localities. It usually has reference to the degree of rise in volume a loaf undergoes before being put in the oven. In this sense, by a well-proved loaf is understood one that has risen well, both in the dough stage and after being placed in the oven. It almost goes without saying that in judging the quality of a loaf the baker likes it to be as large as possible. Such an opinion is a sound one where size of the loaf is combined with evenness of texture, and is not the result of the presence of large cavities in the bread. The opposite of a well-proved loaf is a heavy one; hence this matter of the proof of a loaf is of importance. The loaf which in this particular looks the best is that which is most digestible and wholesome.

There is another sense in which the term "proof" is applied: thus, two loaves may have risen equally well, and yet the one be regarded as being better proved than is the other. The well-proved loaf is, under these circumstances, viewed as that in which fermentation has proceeded until the flavour of the bread (the bouquet, if the term may be borrowed) has developed to the greatest perfection. The well-proved loaf will be sweet and nutty in flavour, and have all the characteristics of being thoroughly cooked; the badly-proved loaf will be lacking in flavour, and have what, for want of a better expression, may be called a "raw" taste. Undoubtedly, this use of the term "proving" refers to a difference which does exist in the two loaves, a difference which in all probability is due to the more or less perfect proteolytic action of the yeast on the proteins during fermentation. The term proof is therefore used in two different senses, one as a measure of the volume of the loaf, the other as an indication of the extent to which the changes accompanying fermentation have proceeded.

716. Pile.—This is essentially a term referring to the texture of the crumb of bread, and is doubtless derived from the use of the word "pile" as indicating the texture of the surface of velvet. In a letter, of which the following is the substance, Mr. W. A. Thoms explained to one of the authors the exact sense in which the term is used in Scotland:—"By a well-piled loaf we do not understand a loaf well risen. Pile is the gloss of the outside skin, or crumb of close-packed bread, and the more unbroken the skin, the more silky in feel and glossy in sheen, the higher we rank the pile. Undoubtedly a well-piled loaf must also be a well-risen loaf. They have that in common, but a well-risen loaf may be ragged, broken-skinned and dark, without being over proved; such a loaf we call coarse, and say it has a bad or no pile. Proof, in dough or baked bread, refers to volume or size. These qualities, proof and pile, are due to the same factor, carbon dioxide, acting on and distending the gluten, and it is the condition of the gluten at the time in the oven, when the dough is passing into bread, that determines the pile. The condition, good or bad, of the gluten in this transition state may be due to the condition of the flour, the proportion of gluten it contains, or to the action of the yeast and its by-products on the gluten during the entire fermentation. Unhealthy yeast will produce an abnormal proportion of acids, and acids render gluten first friable and then soluble. At the friable stage, bread may be high, badly shaped, dark and ragged, but deficient in pile."

717. Odour.—This is best judged by pulling a loaf open and burying the nose deep in the cleft. The bread should have a nutty, sweet smell; this denotes the highest degree of excellence so far as this quality is concerned. There may be an absence of smell, or what is perhaps most forcibly described as a mawkish and damp odour; these belong to the indifferent stage. The bread may smell sour, in which case an unfavourable opinion is naturally formed. Beyond these are the smells, approaching to stenches, arising from butyric, ropy, and even putrid fermentation.

718. **Flavour.**—This of course is one of the most crucial tests to which bread can be put. It is probably the only one adopted by the vast majority of the bread-eating public. Fortunately, the judgment based on flavour is almost invariably a sound one; a bread which pleases the palate is usually one that is wholesome. Having made this statement, it may be well also to indicate one direction in which the palate test is untrustworthy; many people are extremely fond of hot rolls for breakfast. These luxuries are not, however, to be indulged in by every one, for hot bread is not easily digestible. The reason is a simple one; the soft nature of bread, while still warm, causes it to be formed into balls in the mouth, which are swallowed without the due admixture with saliva.

When tasting bread, nothing having a strong flavour should have been eaten for some little time previously; a small piece of the bread should be put in the mouth, masticated, and allowed to remain there a short time before being swallowed. The flavour should be sweet, and of course there must be an absence of sourness or any marked objectionable taste. The physical behaviour of the bread in the mouth is also of importance. The bread should not clog or assume a doughy consistency in the mouth; neither, on the other hand, must it be dry or chippy. In addition to tasting the dry bread, a slice spread with butter may be eaten. It need not be said that in this test the butter must be unexceptionable.

719. **Colour and Thickness of the Crust.**—The crust should be of a rich brownish yellow tint; neither too light on the one hand, nor too dark on the other. So far as is consistent with adequate baking, the crust should be as thin as possible.

The act of baking changes the character of several of the constituents of the flour. Thus, the albumin is coagulated, and thereby rendered insoluble. The starch is partly, at least, rendered soluble by the gelatinisation consequent on heating. The fatty matters of the flour are unchanged; at times, however, bread is found to contain fat over and above that normally present in flour. In fancy bread, butter or milk is sometimes used in the dough; small quantities of lard are also employed by some bakers in order to give a special silkiness to the fracture where two loaves of crumby bread are separated from each other. The ash is not materially affected in quantity, except in so far as it is increased by the addition of salt. The water varies considerably. Subjoined are the results of some analyses collected by König and quoted by Blyth. A number of others by the authors are given in various parts of this work:—

	Minimum.	Maximum.	Mean for Fine Bread.	Mean for Coarse Bread.
Water	26.39	47.90	38.51	41.02
Nitrogenous Substances ..	4.81	8.69	6.82	6.23
Fat	0.10	1.00	0.77	0.22
Sugar	0.82	4.47	2.37	2.13
Carbohydrates (Starch, etc.) ..	38.93	62.98	49.97	48.69
Woody Fibre	0.33	0.90	0.38	0.62
Ash	0.84	1.40	1.18	1.09

720. **Quantity of Water in Bread.**—The question may fairly be asked—On what principle is a decision to be made as to whether a bread

contains too much water? In reply, the loaf having become cool, say 2 hours after being removed from the oven, should on being cut feel just pleasantly moist, not dry and chippy, nor on the other hand in the slightest degree sticky or clammy. A second loaf, on being examined in the same way when 2 days old, should answer to the same tests, and should not show the slightest signs of sourness or mustiness. Some loaves of bread containing even 40 per cent. of water would very well pass this examination; while others which might contain much less water would nevertheless be damp and sodden, rapidly turning mouldy or sour. Notwithstanding that the latter contained absolutely the less water, they would still be condemned as containing more than they ought; while the former would be returned as coming within the limit. The quantity of water permissible in a bread must depend on the nature of the flour used; the offence is not in using sufficient water to a strong flour, but in adding more to a weak flour than it can properly take.

Another question arises—Would it not be well for the public to insist on being supplied with bread made from such flours as normally require, for their conversion into bread, a low proportion of water? Again, in reply, the strongest flours—that is, those which naturally absorb the most water—are made from the most nutritious, soundest, best matured, and highest class wheats; so that the baker who uses a flour with high water-absorbing capacity, uses also a high priced flour.

721. Standard for Moisture.—By legal enactment the quantity of moisture present in bread of standard quality may not exceed 31 per cent. in the district of Columbia, U. S. A. (*Foods and their Adulteration, Wiley.*)

As against this, Wiley regards 35 per cent. of moisture as being the average quantity in typical American high-grade bread (see paragraph 525).

As an example of excessive water, Cameron states that bread supplied in August, 1896, to the troops at Clonmel, county of Tipperary, Ireland, contained per 100 parts:—

Water	58.28
Organic Matter	40.57
Ash	1.15
	100.00

(*Analyst,* 1896, *p.* 255.)

722. Analytic Estimations.—In an ordinary analysis of bread, where the object is not to test for adulteration, the estimations given below may be made. A thin slice should be cut from the middle of the loaf, the crust cut off, and then the interior portion crumbled between the fingers; the crumbs must be thoroughly mixed, and at once placed in a bottle.

Moisture, Ash, and Phosphoric Acid.—Determine as directed in paragraph 708 on Malt Extracts.

Proteins.—Determine by Kjeldahl's method on 1 gram of the bread.

Acidity.—Take 10 grams of the bread, grind up in a mortar with a small quantity of water, transfer to a flask, and make up to 100 c.c. Allow to stand for an hour in a boiling-water bath, cool, and titrate with $N/10$ soda, using phenolphthalein as an indicator. The acidity may be calculated as lactic acid.

Fat.—Direct extraction of bread with ether or light petroleum spirit, however long continued, gives too low results, owing to the fat being enclosed by the starch and dextrin. The results are lower than those obtained from the flour from which the bread was made. The following method, slightly modified from that suggested by Weibull, gives trustworthy results, but it is necessary to work exactly as follows:—4 grams of new or 3 grams of stale bread or dried bread solids are put into a 70 c.c. beaker, and covered with 15 c.c. of water, after which is added 10 drops of dilute sulphuric acid (25 per cent.). The beaker is then placed in an ordinary saucepan containing a little water, the lid put on, and the contents boiled gently for at least 45 minutes, or till the solution gives no starch reaction with iodine. While still warm, the contents are carefully neutralised with slight excess of powdered marble or pure precipitated calcium carbonate. The mixture is then heated over a water bath, or by standing on the top of the hot-water oven, until concentrated to about 10 c.c., when it is spread on a strip of stout blotting-paper (such as is used in Adam's milk process, being 22 inches long by 2½ inches wide), and any liquid remaining in the beaker is removed by means of a piece of cotton-wool, which is then put on to the filter paper. The latter resting on iron gauze, is first dried for 10 minutes at 100° C. The paper is now rolled into the usual shape, and then dried for 3-4 hours at 100-103°. After this it is placed in a Soxhlett's apparatus, and extracted for about 60 times with ether or light petroleum spirit, the extraction occupying in all about 5 hours. The ether solution is then evaporated, and dried in a weighed dish in the usual manner.

The following analytic results show very clearly the relation between the fat as determined by direct extraction, that by Weibull's method, and the fat contained in the meal or flour:—

I. Analysis of fancy loaf containing lard, the fat being determined by direct extraction.

II. Analysis of same, by one of the authors, the fat being determined by the method above described.

III. Analysis of same by another analyst, fat determined by similar method.

IV. Analysis of plain bread, made and analysed by one of the authors.

V. Analysis of fancy loaf containing according to the recipe ½ lb. of lard, made and analysed by one of the authors.

VI. Analysis of "all new milk" bread, made and analysed by one of the authors.

In the first table all the percentages of the various constituents are calculated for purposes of comparison to the same proportion of water as was originally found in No. I. analysis.

In the second table is shown the percentage composition of the bread in the dry state.

TABLE I.

Constituents.	I.	II.	III.	IV.	V.	VI.
Water	40.49	40.49	40.49	40.49	40.49	40.49
Proteins (Albuminoids), Gluten, etc..	7.55	7.32	—	7.43	7.55	8.74
Fat	0.96	1.85	1.81	0.95	2.16	1.84
Starch, etc.	38.97	—	—	—	—	—
Soluble Matter, principally Carbohydrates	10.30	12.16	12.19	6.31	15.18	8.16
Mineral Matter	1.73	—	1.87	1.11	1.37	1.28

TABLE II.

	I.	II.	III.	IV.	V.	VI.
Proteins (Albuminoids), Gluten, etc..	12.68	12.31	—	12.49	12.70	14.70
Fat	1.60	3.12	3.05	1.60	3.63	3.10
Soluble Matters, principally Carbohydrates	17.30	20.44	20.50	10.62	25.52	13.72
Mineral Matter	2.90	—	3.15	1.88	2.32	2.16

The mixed meal used in Nos. IV., V. and VI. contained 1.47 per cent. of fat, equal to 1.69 per cent. in the meal in the dry state. Ordinary white bread contains on an average in the dried solids:—Fat, 0.7 to 1.14 per cent.; soluble matter, 5.0 to 8.0 per cent.; ash or mineral matter, about 1.5 per cent., of which about 1.0 per cent. is common salt. In the recipe for the fancy loaf, the addition of the ½ lb. of lard, if the same is perfectly pure, raises the calculated percentage of fat on the dried bread solids by the amount of 2.07 per cent. which agrees almost exactly with the results of analysis. These figures do not confirm the view sometimes expressed, that a part of the fat of flour is in bread-making volatilised in the oven.

Soluble Extract.—Take 25 grams of the bread and 240 c.c. of water, rub down with a little of the water into a perfectly uniform paste in a mortar. Transfer to a flask, add the remainder of the water and 1 c.c. of chloroform. Or, as an alternative method, the bread may be moistened with a little of the water and then rubbed through a fine sieve. The small thimble-shaped strainers, sold for attaching to the spout of a tea-pot in order to strain the tea, answer well for this purpose. The strainer is then washed with some more of the water and the whole transferred to a flask. Shake vigorously at intervals during 12 hours, or allow to stand over night. At the end of the time shake again, and allow to stand for half an hour for the solids to settle. Filter the supernatant liquid until perfectly bright, and evaporate 25 c.c. to dryness for soluble extract. Bread contains on the average about 40 per cent. of water, and therefore there are 10 c.c. in 25 grams; this quantity, together with the 240 c.c. added, make 250 c.c. The water extract may therefore be viewed as a 10 per cent. solution of soluble matters. There is probably no generally applicable method which extracts the whole of the soluble matter of the bread, as a portion is almost certain to remain behind. If, on the other hand, the bread be subjected to prolonged boiling, some of the constituents which were not originally soluble are thereby dissolved.

It is not recommended to evaporate the bread to dryness, and make the determinations of soluble matters in the powdered dry residue, as this does not at all readily yield up its soluble matter to water.

Maltose.—Usually 10 c.c. of the soluble extract solution may be taken and precipitated with Fehling's solution in the usual manner. Should the amount of precipitate be very small, another 10 c.c. should be at once added.

Soluble Starch and Dextrin.—These may be determined as described in paragraph 703, Chapter XXIV.

Soluble Proteins.—Take 25 c.c. of the soluble extract solution, evaporate to dryness in a flask, and determine organic nitrogen by Kjeldahl's process. The difference between total and soluble proteins may be returned as insoluble proteins.

Starch.—This is usually taken as difference, after making all other determinations; but it may also be determined direct by either of the various processes given in Chapter XXIV. for estimation of starch. From the total starch, that estimated in soluble extract solution as soluble starch must be deducted.

Cellulose.—This may be determined by the method described in paragraph 704.

CHAPTER XXVI.

ADULTERATIONS AND ADDITIONS.

723. Standard Works on the Subject.—In giving directions for both flour and bread analysis, the authors have hitherto confined themselves to such modes of testing as enable one to determine the quality and character of each, apart from any considerations as to the presence or absence of any foreign bodies. The present chapter contains an outline of the processes employed in the analysis of flour, bread, and certain other substances, for the purpose of detecting adulteration. This branch of chemistry applied to the arts of milling and baking has received considerable attention, and several standard works of reference have been written on the subject; among these may be mentioned those of Allen and Blyth, both of which represent the most recent and authoritative opinions of chemists on the problem. For several of the tests to be hereafter described the authors are indebted to these works, to which the student is referred for further and more detailed information.

724. Information Derived from Normal Analysis.—Some of the tests already mentioned in the description of the normal analysis of flour and bread serve also as indications as to whether a sample is adulterated. Thus the moisture, if unduly high, points to the fact that at some stage of manufacture, water has been added to the wheat, stock, or flour; water added for other purposes than normal conditioning or improvement of the grain or stock must be regarded as objectionable.

The percentage of ash in the flour affords some guide as to whether the sample has been treated with mineral substances. A flour ash, when properly burned, should amount to less than 1 per cent.; greater quantities than this are probably due to mineral adulteration. Reference has already been made to certain considerations arising out of the presence of undue ash for the colour of the flour. See paragraph 648.

725. Impurities and Adulterants of Flour.—The following are some of the foreign substances that are at times found in the ground form in flour: seeds of other plants, as corn-cockle and darnel; blighted and ergotised grains—these are to be viewed rather as impurities than adulterants, the latter term being confined to those bodies wilfully added for purposes of fraud. Among these latter are rye, rice-meal, maize flour, potato starch, meal from leguminous plants, as peas and beans, and alum and other mineral bodies. The question of the addition of mineral substances as "improvers" has been already discussed in Chapter XVII.

The tests for many of these substances are in part microscopical; the chapters containing directions for practical microscopic work provide information and data as to the making of such tests. The following are the principal chemical tests for the bodies above mentioned:—

726. Darnel.—Treat a little of the flour with alcohol (rectified spirits of wine, not methylated spirits), digest at 30° C. for an hour; shaking occasionally. Filter and examine the filtrate. This should be clear and colourless, or at most should be only of a light yellow colour. In the event of the flour containing darnel, the alcoholic extract is of a greenish hue, and has an acrid and naüseous taste.

Treatment with alcohol and a small quantity of acid is a useful test for other adulterants. Extract the flour with 70 per cent. alcohol (*i. e.*, a mixture of alcohol and water, containing alcohol equivalent to 70 per cent. of absolute spirit), to which 5 per cent. of hydrochloric acid has been added. Pure wheat or rye flour yields a colourless extract; barley or oats gives a full yellow tint; pea-flour, orange-yellow; mildewed wheat, purple-red, and ergotised wheat, a blood-red colouration.

727. Ergot and Mould.—To test flour for ergot, exhaust 20 grams with concentrated alcohol in a fat extraction apparatus; notice the colour, which in the presence of ergot is more or less red. Mix this solution with twice its volume of water, and shake up separate portions of this mixture with ether, amyl-alcohol, benzol, and chloroform. Ergot imparts a red colour to the whole of these solvents.

Vogel recommends the flour should be stained with aniline violet, and then examined under the microscope; should any of the starch granules have been attacked by ergot or other fungoid growths, they acquire an intense violet tint; while if they are perfectly sound, they remain comparatively colourless.

Ergotised flours evolve the peculiar fish-like odour of trimethylamine when heated with a solution of potash: the same smell is, however, evolved by flour otherwise damaged. The test is of service in distinguishing between sound and unsound flours.

The use of mouldy wheat for the manufacture of flour can be detected by placing the sample in a tightly stoppered bottle, damping it and placing it in a bath heated to about 30° C. Any mouldy taint can readily be observed after thus standing for 2 or 3 hours.

728. Rice in Flour, Gastine.—Gastine recommends for the detection of rice in wheaten flour its treatment with a colour stain. A trace of the flour is treated with a solution of 0.05 gram of aniline blue in 100 c.c. of 33 per cent. alcohol. The flour is then dried at about 30° C., and finally by heating for a few minutes at 110-113° C. The preparation is then mounted in cedar-wood oil and examined under the microscope. Treated in this manner the wheat starch granules are almost invisible and very rarely do they even exhibit a visible hilum. On the contrary the hilums of the minute rice starch granules show up very distinctly, and usually in regular clusters, since each fragment of rice is generally built up of a number of starch granules. When wheat granules are cracked, the fissures show very distinctly as a result of the infiltration of nitrogenous matter, which readily takes the stain. Granules of maize and buckwheat starches behave like rice. (*Comptes rend.*, 1906, **142**, 1207.)

729. Maize Meal in Wheaten Flour, Kraemer.—Kraemer states that flours containing corn-meal give off an odour of roasting corn when heated in glycerin to boiling for a few minutes. (*Jour. Amer. Chem. Soc.*, 1899, 662.)

730. Maize Starch in Wheaten Flour, Baumann.—For the detection of maize starch (corn flour) in wheaten flour, Baumann recommends the following test:—About 0.1 gram of the flour under examination is mixed with 10 c.c. of a 1.8 per cent. solution of potash, and the test tube shaken at intervals during 2 minutes. Four or five drops of 25 per cent. diluted hydrochloric acid are then added and the tube again shaken. The liquid must still be slightly alkaline in order to prevent the precipitation of the dissolved proteins. A drop is taken out and examined under the microscope, when the wheat-starch granules will be found to be completely ruptured while those of maize are unaltered. As little as from 1 to 2 per cent. of maize can thus be detected. The test may be employed quantitatively by taking mixtures containing known quantities of maize starch, treating them in the same way as the sample under examination, and deciding which matches it when drops of similar size are microscopically examined. The same method is applicable to the detection of maize in rye flour. (*Zeits. f. Untersuch., Nahr.-u Genussmittel,* 1899, **2**[1] 27.)

731. Maize in Wheaten Flour, Embrey.—Embrey has not found the foregoing process to give satisfactory results in his hands, and has therefore devised and recommends the following modification:—Mixtures of pure wheat and maize flours are prepared containing respectively 10, 15, 20, 25 and 30 per cent. of the maize. Weighed quantities (0.2 gram) of each of these, and of the sample under examination, are placed in test tubes (15 c.m. × 2 c.m.) which are fitted with paraffined corks. To each is added a quantity of 20 c.c. of potassium hydroxide solution (18 grams per litre), and the tubes shaken uniformly for 3 minutes. Twelve drops of diluted hydrochloric acid (HCl of specific gravity 1.16, 50 c.c.; water, 100 c.c.) are next introduced and the tubes shaken, and then whirled in a centrifugal machine at 600 revolutions per minute. One c.c. of the clear liquid is transferred to a Nessler tube and diluted to 50 c.c., after which 1 c.c. of an iodine solution (I, 0.25 gram; KI, 1 gram; water to 250 c.c.) is added. The tint obtained compared with those of the standard tubes gives the proportion of maize within about 5 per cent. For a more exact determination, 10 c.c. of the clear liquid from each tube are boiled for 2 hours with 1 c.c. of dilute sulphuric acid (1:7), then neutralised, diluted to 50 c.c. and run from a burette into a boiling mixture of Gerrard's solution, 10 c.c., and Fehling's solution, 2 c.c., until the colour is discharged. The percentage of maize is obtained from the standard tube of which the same amount is required to discharge the colour.

Gerrard's Solution is prepared by diluting 10 c.c. of freshly prepared Fehling's solution with 40 c.c. of water, and adding a solution (about 5 per cent.) of potassium cyanide from a burette, until the blue colour is only just perceptible. During the addition of the cyanide, the diluted Fehling's solution is kept boiling and constantly stirred in a porcelain dish. (*Analyst,* 1900, **25,** 315.)

This process is really an estimation of the soluble starch resulting the rupture of the granules of wheaten starch by the action of potassium hydroxide solution. In the first method it is directly estimated as starch by a colorimetric process with iodine; and in the second by conversion into glucose and then volumetrically by a modification of Fehling's solution. An objection to the method is that variations in the proportion of wheaten starch in a flour may be due to causes other than the presence of maize. Thus a very weak flour may contain more starch than a very strong one, and if the former be also exceptionally dry and the other comparatively moist the difference is still further enhanced. Also, if even as much as 30 per cent. of maize flour is contained in the flour the actual reduction in wheat starch is only approximately from about 70 to 50 per cent. On the other hand the amount of maize flour will have been increased from zero to 30 per cent.; obviously, therefore, a direct estimation of the maize starch is preferable if practicable. As a modification of Embrey's method it is suggested that the solution of clear starch should be decanted off, the insoluble residue thoroughly shaken up with water, and again whirled in the centrifugal machine, so as to free it as far as possible from soluble starch. The residual maize starch may then be dissolved by heating with water, and estimated either colorimetrically with iodine, or by conversion into glucose and estimation by Fehling's solution The most important point here is whether or not the sediment is practically free from soluble wheaten starch.

In the discussion on the above paper, Bevan mentioned with approval a qualitative method devised by Wilson, and consisting of mixing the flour with clove oil, and examining with a ¼ or ⅛-inch objective, when the hilum of maize appears as a black dot or star, while wheaten and other starches are practically invisible.

732. Starch in Yeast.—Bruylants and Druyts recommend the following method of estimating flour or starch in yeast: From 50 to 100 grams of the yeast are to be taken, according to the suspected quantity of starch, and mixed thoroughly with a dilute solution of iodine in potassium iodide. The mixture is, if necessary, passed through a fine sieve in order to remove any large sized fragments of impurity. It is then allowed to settle, when the starch falls first, until the starch is covered by a thin layer of yeast. The yeasty liquid is poured away and this washing by decantation continued until only starch remains. A little fresh iodine must be added from time to time. The sediment is dissolved and converted into glucose by heating with dilute (2 per cent.) hydrochloric acid, and then estimated in the usual manner. In tests made on yeasts containing known quantities of starch, ranging from 3 to 15 per cent., the amounts recovered by the method ranged between 96.7 per cent. and 100.8 per cent. of the added starch. (*Bull. Assoc. Belge des Chim.*, **13** [1] 20.)

Instead of dissolving the starch obtained by this process in hydrochloric acid, it may be estimated direct by first washing with strong alcohol and then evaporating and drying in a tared dish. Comparative experiments should be made on yeasts to which known quantities of starch have been added.

733. Aniline Blue in Flour, Violette.—Violette states that blue colouring matter is sometimes employed in order to counteract the yellow tinge of flour. In order to detect such addition a sheet of white filter paper is floated on the surface of water, and a little of the suspected flour sprinkled thereon. In the presence of aniline colours, dark specks soon appear on the paper, which grow in size and form blue spots. (*Bull. Soc. Chim.*, 1896, **15**, 456.)

734. Mineral Adulterants and Additions.—The presence or absence of most foreign mineral matters will have been indicated by the percentage of ash yielded. Alum is, however, added to flour in quantities too small to be thus detected. One of the most ready means of separating mineral substances from flour is by means of what is termed the

735. Chloroform Test.—This test depends on the fact that chloroform has a density higher than that of the normal constituents of flour, but lower than that of minerals generally; consequently, on agitating a mixture of flour and chloroform, and then allowing it to rest, the flour rises to the surface, and any mineral adulterants sink to the bottom. On the small scale, for the purpose of a qualitative test, a large dry test-tube may be about one-third filled with the flour, then chloroform added to within one inch from the top. The tube must then be corked and violently shaken, after which it must be allowed to rest for some hours; the mineral matter will then be found to have sunk to the bottom. For quantitative purposes a glass "separator" is requisite. This is a cylindrical vessel some 2 inches in diameter, 8 or 10 inches in length, stoppered at the top, and furnished with a stopcock at the bottom. Introduce in this vessel 100 grams of the flour and about 250 c.c. of methylated chloroform; treat as directed for the smaller quantity. When the separation is effected, open the stopcock and allow any sediment, with as little as possible of the liquid, to run through. Treat this again with a little more chloroform in a smaller separator, and once more drain the sediment off through the stop-cock into a watchglass, or small evaporating basin.

Allow the chloroform to evaporate; treat the dry residue with a small quantity of water, and filter. Any plaster of Paris, calcium phosphate, or other insoluble mineral matter will remain on the filter, and may be ignited and weighed. Evaporate the solution to dryness, and examine the residue carefully with a low power under the microscope for any crystals of alum.

In making this test, flours, which are absolutely free from any added mineral matter, occasionally give a slight sediment. This was formerly ascribed to the presence of detritus from the millstones; but this can scarcely be an adequate explanation, as the authors have obtained such sediment from pure roller-milled flours.

736. Special Test for Alum.—The most convenient test for alum in flour consists in adding thereto an alkaline solution of logwood. Take 5 grams of recently cut logwood chips and digest them in a closed bottle with 100 c.c. of methylated spirit. Also make a saturated solution of ammonium carbonate. Mix 10 grams of the flour with 10 c.c. of water, then add 1 c.c. of the tincture of logwood and 1 c.c. of the ammonium carbonate solution, and thoroughly mix the whole. With pure flour the resultant mixture is of a slight pinkish tint. Alum changes the colour to lavender or full blue. The blue colour should remain on the sample being heated in the hot-water oven for an hour or two.

737. Mineral Matters in Solution.—Certain mineral matters are at times added to flour in the state of solution, the solution being sprayed into the flour or added to a portion of the stock which is then dried, ground, and mixed in with the flour. If this operation is performed with sufficent care no particles of the flour are sufficiently weighted by the adherent mineral matter to sink in chloroform, and so the application of that test fails to reveal the presence of such added mineral matter. Very frequently, however, some portion of the flour has absorbed sufficient of the mineral addition to sink in chloroform. If so, this portion should be thus separated and the ash in the two portions determined. Any difference detected is an indication of the addition of some foreign mineral. The nature of the substance added may be ascertained by further analysis of the ash.

In cases where it is desired to test particularly for sprayed additions of mineral salts, it is well to compare the total ash of the flour with that of a sample of known purity of the same colour and grade, bearing in mind Snyder's conclusions on the relation between ash and grade of flour already given (paragraph 648). In this connection it must be borne in mind that a bleached flour will contain less ash than a corresponding unbleached flour. In the next place apply the chloroform test as described. Should this fail, add to the chloroform and flour in the separator, absolute alcohol in small quantities at a time, and shake and allow to settle between each addition. As the mixed liquid approaches in density to that of flour, a point is reached at which any mineral-weighted particles of flour may sink and the purer portion float on the top. In this case separate the two and determine the ash in each separately. If deemed necessary, make analyses of each portion of ash. Should the whole of the flour have absorbed the mineral addition with absolute uniformity, a separation cannot of course be effected by this method. But in all such methods of introducing foreign mineral matters, some portion of the flour is almost certain to have absorbed more mineral matter than others. If the addition is exceedingly small, this mode of separation is not likely to be effective, and recourse must be had to a more or less complete analysis of the whole ash. The finding of any substance in a quantity beyond the extreme amount that may occur as a natural constituent of flour is evidence of its presence as an added body. In the event of the addition of mineral substances to a flour which is naturally deficient in those substances, and in such quantity as not to exceed the normal amount which may be present, then even a complete analysis of the ash may fail to reveal the fact of mineral bodies having been added. More usually, however, any such additions will not have the same proportionate composition as normal flour ash, and in this way their presence will be indicated.

738. Alum in Bread.—Bread is tested for alum by first taking 5 c.c. of the tincture of logwood, 5 c.c. of the ammonium carbonate solution. and diluting them down to 100 c.c. This mixture must at once be poured over about 10 grams of the crumbled bread in an evaporating basin. It is allowed to stand for 5 minutes, and then the superfluous liquid drained off. Slightly wash the bread and dry in the hot-water oven. Alum gives the bread treated in this manner a lavender or dark blue colour, which is intensified on drying. Pure bread first assumes a light red tint, which fades into a buff or light brown. After some practice this test gives satisfactory results, and is so sensitive that as little as 7 grains of alum to the 4 lb. loaf have been detected. The depth of colour affords a means of roughly estimating the quantity of alum present. It is essential that the tincture of logwood be freshly prepared, and that the test be made immediately after mixing the tincture of logwood and ammonium carbonate solution.

739. Young on Logwood Test for Alum.—In 1886 Young pointed out (*The Analyst*) that under certain circumstances bread which is absolutely free from alum gives the characteristic reaction with logwood. On investigation it was found that the flour used gave no indication by logwood, but that the bread gave a very distinct colouration. The sample was heavy and sour—subsequent experiments showed that the colouration was directly due to the acidity. On taking pure breads, which were absolutely negative to the logwood test, and moistening with dilute acetic acid (1 to 250 of water), and letting stand for one hour, all gave a most intense blue colour with logwood. So also did pure flour similarly treated. Young considers this effect to be due to phosphate of alumina (a body normally-produced from the mineral constituents of flour) being slightly soluble in dilute acetic acid, and quotes experiments in proof of this solubility. He further found that such phosphate of alumina exists in a state of combination with the gluten, and, as a result of careful washing, was able to procure starch, which, after treatment with acetic acid and subsequent application of the logwood test, gave no colouration.

In a quantitative experiment some best quality Hungarian flour was taken, yielding 0.7 per cent. of ash and 8 per cent. of dry gluten. The gluten was washed out in a muslin bag and dried, 20 grams were taken, finely powdered, and treated with 250 c.c. of 50 per cent. acetic acid, and heated in the water bath for 28 hours. The gluten had then dissolved, leaving a sediment, from which the clear liquid was poured, and the residue again twice treated in the same manner with the diluted acetic acid. The three lots of acid extract were evaporated to dryness, and the residue burned to a perfect ash—this was treated in dilute hydrochloric acid, and the insoluble residue fused with alkaline carbonates, dissolved in dilute hydrochloric acid, filtered, and filtrate added to acid solution of ash. This was again evaporated to dryness, redissolved in small quantity of hydrochloric acid, filtered, filtrate boiled, and cautiously added to 25 c.c. of saturated solution of pure sodium hydroxide, also boiling, and kept boiling for a few minutes. The precipitate was dissolved with hydrochloric acid, and precipitated with saturated solution of sodium phosphate and slight excess of ammonia. After 10 minutes' boiling, the precipitate of aluminium phosphate was collected, filtered, and weighed. The 20 grams of gluten yielded 0.0185 gram of aluminium phosphate, equal to 0.01875 from 250 grams of flour, or 0.0075 per cent. Alumina was thus shown to be a natural constituent of flour, and associated with the gluten. The alumina thus normally present justifies a deduction being made of from 7 to 8 grains of alum per 4 lb. loaf from the amount corresponding to total alumina by analysis.

For further experiments by Young on the solubility of aluminium phosphate in acetic acid, the reader is referred to *The Analyst* for April, 1890. He there shows that the presence of ammonium acetate, and also that of ammonium chloride, prevent the complete precipitation of aluminium phosphate in the presence of acetic acid.

740. Calcium Sulphate in Bread.—Calcium sulphate is occasionally found as an added substance in bread. The addition is probably due to the aëration of the bread by a phosphatic baking powder, in which the acid phosphate contains calcium sulphate as a natural impurity. As only traces of sulphates exist ready formed in the cereals, they may be detected by an examination of the unignited bread. The best plan is to soak 12.20 grams of the bread for some days in 1200 c.c. of cold distilled water until mould forms on the surface of the liquid. The solution is then strained through muslin and the filtrate treated with 20 c.c. of phenol distilled over a small quantity of lime. The whole is then raised to the boiling point and filtered through paper; 1000 c.c. of the filtrate are slightly acidulated with hydrochloric acid and precipitated in the cold by barium chloride. Every 237 parts of barium sulphate represent 136 parts of calcium sulphate. (*Allen's Commercial Organic Analysis.* vol. 1., p. 460.)

741. Mineral Oil for Parting Loaves.—In the case of close-packed bread it is the custom to smear the contiguous surfaces of loaves with melted lard or oil for the purpose of preventing their sticking together. For this purpose a petroleum residue is employed (1896) in Germany, known as Brötel. Illness has been traced to this practice in Hamburg, the residue remaining in the loaf and causing digestive disturbances. (*Jour. Soc. Chem. Ind.,* 368, 1896.)

742. Colouring Matter in Cakes.—In order to determine whether cakes and other confectionery have been coloured with yolk of egg, or with other colouring matters, Spaeth recommends that the fat be extracted and examined. The following are the characteristics of egg-yolk fat and wheat meal fat respectively:—

	Egg Fat.	Wheat Fat.
Sp. g. at 100° C. (water at 15° = 1.00)	0.881	0.9068
Melting point of fatty acids	36°	34°
Saponification number	184.43	166.5
Iodine value	68.48	101.5
,, ,, of fatty acids	72.6	—
Reichert-Meissl value	0.66	2.8
Refractive index at 25° C.	1.4713	1.4851
,, ,, on Zeiss refractometer scale ..	68.5	9.20

When the iodine value exceeds 98, and the phosphoric acid (P_2O_5) in the fat is below 0.005 per cent., there cannot be more than traces of egg-yolk. (*Analyst,* 233, 1896.)

In this proposed method, no cognisance is taken of the fact that cakes and similar articles have large quantities of butter and other fats added to them, the constants of which may vary widely from those of either egg-yolk or wheat fats.

CHAPTER XXVII.

ROUTINE MILL TESTS.

743. Practical Adaptation of Flour Tests to Mill Routine.—The foregoing chapters have contained descriptions of the modes of making various flour tests and the conclusions to be drawn therefrom. There now remains for discussion the problem of their adaptation to commercial milling routine. This may be done in two ways, either by the employment of a chemist at the mill, or by sending samples by arrangement to a chemist who undertakes work of this class. In either case some special training is requisite. A professional knowledge of the science of chemistry and the principles of analysis is of course essential; but in addition to these a chemist who undertakes the work of commercial flour analysis should be familiar with the general properties of wheats and of flour. He should also have had sufficient experience of the physical methods of testing employed by both miller and baker, and of the carrying out of baking tests under conditions of scientific accuracy. In cases where it is decided to carry on such work at the mill, a laboratory must be provided; of this some description has been already given in Chapter XX. on Analytic Apparatus.

744. Dispatch of Samples and Results.—If the alternative is adopted of entrusting these duties to an outside chemist, then arrangements must be made for the collection of the necessary samples and their dispatch. It should be made the special business of some responsible person to take the samples at some specified time. This person must be familiar with the process of sampling, and must take care that the samples are properly representative of the bulk. The quantities must depend on the nature of the tests to be made. Among some of the most frequent of such tests are those of moisture. For each of these an ounce of the material is sufficient. Having regard to the ease with which wheat products either absorb or lose moisture, the samples for this purpose must at once be packed in air-tight receptacles. Probably the most convenient form is a glass tube of the requisite size, fitted with an india-rubber cork. Special wooden blocks are made for holding these for postal purposes; any desired number can then be packed in the one block and dispatched by post. For an ordinary analysis, an 8 oz. sample is a suitable quantity, and a convenient package consists of a small bag made of fine close-textured canvas or similar material. This in turn should be enclosed in a tin canister with tightly fitting lid. Wooden boxes should be provided to hold a certain number of these canisters, for dispatch to the chemist's laboratory. The locks of these boxes should be provided with two keys to be held respectively by the forwarder and recipient. A systematic course of labelling must be adopted. The labels should be *affixed* to the bags or glass tubes, and not to the covers of canisters or the corks of tubes. The reason is that **the identifying label must not be capable of detachment from the sample by the act of opening the package.** Further, the label should bear the name and address of the sender. A proper dispatch book must be kept in which descriptions of samples, identifying marks or numbers, and dates of dispatch are entered. For baking tests, a larger sample must be sent, and for this 2 lbs. is a very convenient quantity. Larger bags of the same kind of material as before are on the whole most suitable. It is not absolutely necessary that they be enclosed in tin canisters, but they should also be packed in wooden boxes. The sample sent for baking will also serve for the other analytical tests, *except* that for moisture. The small samples for this purpose should always be packed in the air-tight tubes; and the larger carrying boxes may be easily fitted with a small division to hold the tubes. The packed sample cases should so far as possible be regularly forwarded by a certain mail or train. There are very few districts in which samples cannot be dispatched in the evening so as to be in the hands of the chemist early the next morning. He will of course be perfectly familiar with the routine of treatment on their reception, the only suggestion to be made being that such results as are wanted most quickly should be arranged for first. For example, moistures are frequently required with the utmost expedition, and the determinations should therefore be started immediately.

In returning results, they may frequently require to be sent by telegraph; in that case a code should be arranged by which the data could be sent cheaply and with the least possible risk of mistake. A certain number of figures can always be sent as a word; but figures are prone to mistakes in transmission, and above all such mistakes are not evident on the face of them. Code words are not so liable to the same errors, and should therefore be used in preference. As an example, the following is a convenient and simple code for the transmission of moisture results.

9.0	Aback	10.0	Babel	11.0	Cabin	12.0	Dark
9.1	Abbey	10.1	Bank	11.1	Cask	12.1	Date
9.2	Accent	10.2	Beach	11.2	Chart	12.2	Dean
9.3	Adder	10.3	Beef	11.3	Civil	12.3	Dell
9.4	Affix	10.4	Bird	11.4	Clamp	12.4	Dip
9.5	Agate	10.5	Blank	11.5	Clock	12.5	Divan
9.6	Aisle	10.6	Blow	11.6	Code	12.6	Dock
9.7	Alarm	10.7	Boast	11.7	Court	12.7	Dose
9.8	Ambit	10.8	Box	11.8	Crest	12.8	Drag
9.9	Anchor	10.9	Buoy	11.9	Cube	12.9	Duel
13.0	Ear	14.0	Fault	15.0	Gas	16.0	Hack
13.1	Ebb	14.1	Fear	15.1	Gear	16.1	Hair
13.2	Echo	14.2	Feud	15.2	Gem	16.2	Head
13.3	Eddy	14.3	Field	15.3	Gill	16.3	Help
13.4	Eel	14.4	Fight	15.4	Give	16.4	Hide
13.5	Effect	14.5	Flock	15.5	Gland	16.5	Hint
13.6	Egg	14.6	Foam	15.6	Good	16.6	Hoax
13.7	Ember	14.7	Fowl	15.7	Gout	16.7	Hole
13.8	End	14.8	Freak	15.8	Grain	16.8	Hulk
13.9	Equip	14.9	Fury	15.9	Gust	16.9	Hurt

All telegraphic results must be confirmed by post, and dispatched so as to be in the hands of the miller at a regular time.

745. Standard Quality.—It must be borne in mind that high quality is not a fixed and invariable standard, but depends largely on what are local requirements. This question most generally arises when systematic tests are for the first time introduced, and requires its proper answer in each individual mill before such tests can yield results of much value. That which is the best flour in the one district is not the best in another, and therefore the chemist first requires to know the exact kind of flour the miller wishes to make. The miller can usually lay his hands on one particular parcel, which has the approval of his most skilful and critical customers, which he would like always to supply, and which he would be content to take as a standard. If he can also obtain certain samples which more or less fall short of this standard, and with clearly marked defects, they will also be of service. The chemist should be supplied with these samples, and his first object should be to find out where the faulty examples differ from the standard one. No precise directions can be given for doing this, since it is here that the skill and judgment of the expert are brought to bear on the problems of each particular flour. Care should be exercised in discriminating between differences which are accidental and those which are fundamental. From these data the requirements in the standard flour for each particular mill are formulated, and the effect of any departures from the standard of quality are duly noted. This is a judgment which cannot be formed immediately; the first opinion must only be looked on as provisional, and must be confirmed or otherwise by subsequent tests. Still it is remarkable how soon, as a result of regular testing, the chemist forms an opinion on the quality of the flour and recognises any deviation. These opinions are usually confirmed by subsequent baking tests.

746. Uniformity in Quality.—Having formulated standards for each miller's requirements, the next object is to see that flours of these qualities are being uniformly produced. For this purpose flours are regularly tested. The first and simplest object of such tests is to serve as a control on the working of the mill, and to secure the most help from such tests the miller (*i.e.*, the working miller) should work in unison with the chemist. So far from being antagonistic, their real duties are complementary, and any real improvement is largely dependent on their mutual co-operation. The miller will take samples from those parts of the mill which will afford the most information, and the chemist will duly test same. In particular if suspicion attaches to the work of any particular machine or part of the mill, samples of the products of this section will receive special attention. In this way tests are made, and the results carefully recorded. In cases where any marked departure from the usual standard occurs, attention should be drawn to it, and the flour watched in its future stages so as to note whether it has been found in any way unsatisfactory in actual use.

747. Actual Routine Tests Employed.—Of set purpose the selection of these is left to the judgment of the individual chemist. In previous pages the nature and objects of the most important tests have been described in detail. The following are among those which will probably be regularly employed.

Moisture.—This test has a very important bearing on the whole question of the conditioning of wheat. Samples may be tested of the whole wheat unmoistened and after the moisture has been added by any means. The comparison of these shows how much water has actually been added. Then tests may be made on the whole wheat, the flour, and the bran. These will show how far and to what extent the moisture has penetrated. Lack of penetration may be due to a particularly hard bran, or it may be the result of conditioning not having been carried out sufficiently long before grinding. Where any system of improving treatment is carried out as a part of the conditioning process, or by the spraying of either stock or flour, the moisture tests serve the secondary purpose of determining the quantities of the improving agents which have actually been added. Moisture tests, intelligently applied, have therefore most important uses in the mill.

Ash.—As a control on the degree of length of patent, regular ash determinations are exceedingly valuable when properly made.

Protein Estimations.—The details of them have been given most fully. The selection must depend on individual judgment. Total proteins, gluten, and alcohol-soluble proteins will probably be included in most schemes of protein determinations.

Water-Absorption.—Viscometer tests not only measure an important property of flours, but also one which serves as a most important check on uniformity of production.

Colour.—In every well conducted mill, the colour of flour is always being carefully watched. This is especially necessary where any bleaching process is being employed.

748. Replacement Tests.—Tests for uniformity are not confined to being a check on the satisfactory working of the mill, but they have a further most important bearing on the difficult question of replacing in a mixture one wheat by another. Some useful general information on this point is given on page 258, but that scarcely more than touches the fringe of the problem. To start with, the same kind of wheat varies with its age, and as the crop from a fresh harvest arrives it must be carefully tested before it can be regarded as the equivalent of that of the preceding year. When a miller is grinding a mixture of several varieties of wheat, and one of these runs out, it is imperative that any proposed substitute shall not seriously alter the character of the flour produced. In making the change he is limited by the facts that the average price of the wheat composing his mixture must not exceed a certain amount, and that the various grades of flour he manufactures must all maintain their specific qualities; and so far as possible must be produced in their usual proportions.

In making any tests on the whole wheats, they may be reduced to fine meal, and the results of gluten or other determinations calculated out on the assumption of a 70 per cent. yield of straight-run flour. Evidently this can be nothing more than an assumption, because the flour yield of wheats varies within wide limits.

Again, for reasons on which the previous subject matter will have thrown some light, the mixing of various wheats does not always produce the expected results. A mixture of strong and weak wheats having a known percentage of gluten, for example, sometimes yields a loaf which is quite appreciably better or worse than was expected, and there is always some anxiety as to the result of a new blend until test bakings have been made on the resultant flour.

749. Milling Tests.—The only true test under these circumstances is the milling test, in which the various wheats are ground separately and their resultant flours tested chemically and by baking. They should then be mixed in the desired proportions and again tested until such a blend is obtained as satisfies the miller's desideratum—a maximum of quality at a minimum of cost. With very small milling plants it is the custom to make a trial by putting a few sacks of a newly arrived wheat through the entire mill. But while this is a tedious and expensive experiment with a small plant, it is practically an impossibility with a large one. The obvious alternative is to lay down a small milling plant for experimental purposes. This must not be too large, and yet must be large enough to make a fairly good commercial sample of flour.

A very convenient plant for making these tests has recently been introduced, which consists of a machine that in a condensed form is able to perform all the operations of a gradual reduction roller plant built in one frame, driven by one main belt and taking up a very little space. This machine is illustrated in Fig. 90, and embodies within itself two pairs of "Break" or fluted rollers, a sieve between the first and second pair, a centrifugal dressing machine to dress the flour from the first break meal and another to deal with the second break stock and tail over the bran to the sack. There is then left the semolina from the tails of the first centrifugal and the bran middlings from the "Cut-off" of the second break centrifugal, to be ground on two pairs of smooth reduction rollers in sequence, each of which is succeeded by a flour dressing reel. The whole process is entirely automatic from the incoming wheat to the marketable products of flour, bran and sharps.

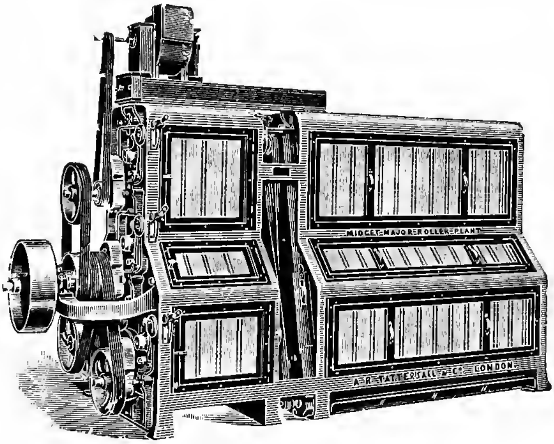

Fig. 90.—Midget Testing Mill.

This useful little appliance, which goes by the name of the "Midget," and is made by Messrs. Alfred R. Tattersall and Co., 75, Mark Lane, London, E.C., lends itself admirably to the testing of small parcels of wheat, as its capacity is to make from 140 to 280 lbs. of finished flour

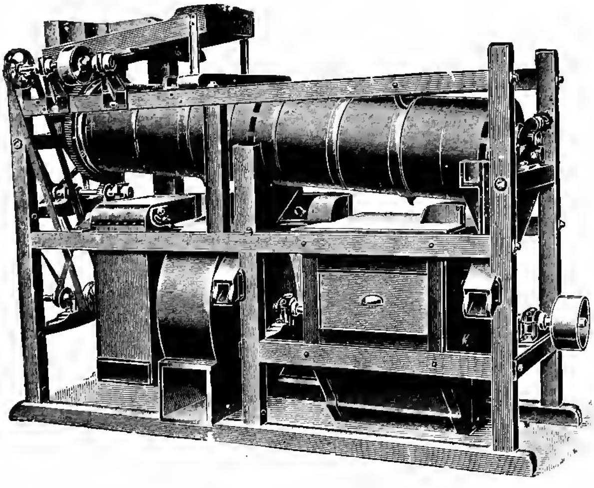

Fig. 91.—Wheat Cleaning Machine.

per hour. By its means a grist can be made from two or even one sack of wheat, and a very passable yield can be obtained. The manufacturers claim that the Midget Mill produces flour equal in every respect to that made in the larger mills of the long system. It may therefore be depended on to yield trustworthy comparative results when used as a wheat and flour testing mill.

A very useful adjunct to testing mills is a cleaning machine made by Messrs. Tattersall and shown in Fig. 91. This little machine goes in very small compass, and has a double sieve to take out large and small impurities by a powerful aspiration. The floor space it occupies is only about 15 in. × 40 in.

Working with a plant of this description, any wheat may be taken, weighed, and milled either with or without conditioning. Its comparative behaviour during milling can be observed, and the total yield of flour determined. Finally the quality of the flour can be tested against, and compared with that of, flour milled from the standard mixture on the same machine.

750. Replacement Calculations.—In making wheat replacements, the following is a very common occurrence. Given a wheat strong in one constituent (C), and another wheat weak in the same constituent (C), it is required to calculate the proportions of each that must be taken to give a mixture that shall have a desired intermediate percentage of C. Thus as an example, a wheat has been in use which has 4 per cent. of C. The only wheats that can be used to replace it are a stronger wheat in that particular respect, containing 5 per cent. of C, and a weaker one containing only 2 per cent. of C. In what proportions must they be used to give a mixture containing 4 per cent. of C?

Stronger wheat, S, contains 5 per cent. of C.
Weaker „ W „ 2 „ „ C.
Mixture, M, is required to contain 4 per cent. of C.

First calculate the quantity of each that will contain 4 parts of C.

As 5 (of S) is to 4 : : 100 : 80
As 2 (of W) : 4 : : 100 : 200
Therefore, 80 parts of S will contain 4 of C.
„ 200 „ W „ „ 4 of C.
and 100 „ M must „ 4 of C.

Call the quantities that will contain the amount of C in M as just indicated, QS, QW, and QM.

Then QS (QW — QM) = amount of S to be taken.
and QW (QM — QS) = „ W „ „
Thus QS (QW — QM) =
80 (200 — 100) = 8000 parts of S to be taken.
and QW (QM — QS) =
200 (100 — 80) = 4000 parts of W to be taken.
Then 8000 parts of S contain 400 of C.
and 4000 „ W „ 80 or C.

12,000 „ M „ 480 of C.
and 100 „ M „ 4 of C.

Of the stronger wheat, therefore, 8 parts must be taken, and of the weaker, 4 parts; or yet more simply in the proportion of 2 to 1.

The following is a somewhat more difficult example:—

S contains 4.3 per cent. of C.
W „ 1.9 „ „ C.
M to contain 2.7 „ „ C.

As 4.3 : 2.7 : : 100 : 62.8 = QS.
„ 1.9 : 2.7 : : 100 : 142.1 = QW.
Then QS(QW — QM) = 62.8(142.1 — 100) = 2643.88 of S.
„ QW(QM — QS) = 142.1(100 — 62.8) = 5286.12 of W.
As S contains 4.3 per cent. of C, 2643.88 of S contain 113.68 of C.
„ W „ 1.9 „ „ C, 5286.12 of W „ 100.40 of C.
7930.00 of M „ 214.08 of C.
As 7930 : 100 : : 214.08 : 2.7 = desired percentage of C.

An inspection of the composition of the mixture shows that it contains as nearly as possible 1 part of the stronger wheat to 2 parts of the weaker one. In percentages, the result works out thus:

As 7930 : 100 : : 5286.12 : 66.66 per cent. of W.
100 — 66.66 = 33.34 „ „ S.

751. Use of Improvers.—When any system of artificially improving flours is in operation, the duty of checking and controlling the same will naturally fall to the chemist whether working in or out of the mill. In the case of the use of a bleaching plant, the miller will exercise his own judgment as to the extent of the bleach he requires. The chemist should compare the reactions of the bleached with the unbleached flour and see that no essential of the flour undergoes any material alteration.

In event of the employment of any process of saline or other treatment, whether by direct addition, spraying, or otherwise, more exacting chemical duties are required. The proportions of saline constituents, sugars, and amylolytic and proteolytic enzymes in what has been called the mill's standard flour should be carefully estimated. It should also be ascertained whether any flours which are below standard show any great deviation in any of the foregoing particulars. Experiments should be made in order to determine whether the addition of these deficient bodies improves the quality of the flour, and if so to what extent they should be added. The object of all these tests is to formulate some definite scheme for the addition of these agents to the flour of each individual mill. Some such data having been acquired, the experimental flours of new wheats should be tested with and without the improving addition, and the system of adding or not adding any improver carried out on a scientific basis. It must be borne in mind that the object of all these additions is simply to remedy the natural deficiencies of some wheats and thus place them on the level normally attained by other wheats without any addition whatever. Important responsibilities are thus cast on the chemist, as non-addition is in some cases as necessary as addition is important in others.

752. Baking Tests.—Not only the control of the testing mill, but also that of the mill's baking tests will probably be within the functions of the chemist. It will be more especially his duty to see that conditions of exactitude, both as to quantities and modes of working, are secured. He will also see that the baking methods used represent as nearly as possible those under which the flour is baked commercially, and will inspect the baked loaves and keep a record of their properties. Under certain circumstances it may be necessary for him to make a more or less complete analysis of the baked bread.

753. Summary of Chemical Functions in Mill.—The preceding paragraphs contain an outline of suggestions as to the adaptation and organisation of chemical functions to milling routine. They apply equally to the performance of such work in the mill or in the laboratory of some outside specialist. The suggestions have not been made too definite, because after all each particular mill's set of problems must be worked out by the chemist to whom they are entrusted. As to the utility of such tests, it must be remembered that the chemical aspect of wheat quality may now be regarded as fairly settled on a scientific basis, and questions involving chemical investigation must continually arise in practical milling if the best results are to be obtained with the greatest commercial success. There is a certain amount of healthy rivalry between what may for convenience be called "chemical" and baking tests on flour. Each has its own merits, but a frequent criticism is that "baking is after all the final test of flour." To this no open-minded chemist will demur, but he will likewise know that his own work also throws most important light and guidance on milling. And this light and guidance are usually of a kind which baking tests are absolutely unable to furnish. It is frequently astonishing to note how in regular routine testing of flours the chemist on observing some departure from the normal is able to predicate successfully an alteration in the quality of the flour. And the importance of the knowledge thus furnished lies in the fact that it is not merely the observation of a result, but is based on the discovery of the cause.

As to the value of chemical work as applied to milling, the following testimony from the Ogilvie Flour Mills Co., Ltd., who were among the pioneers in this direction, cannot fail to be of interest:—

> "I would say that in the operation of mills of large capacity such as we control, our experience has been that laboratory work is one of the absolute essentials to successful and economical operation, and an actual necessity for the maintenance of a uniform product of high quality. We certainly would not for one moment think of dispensing with this feature of our business." (*Personal Communication,* April, 1908.)

One last suggestion may be respectfully made to those who may decide to enlist chemical assistance in their milling operations, and that is to have patience and not expect too much at the commencement. The first task of any chemist will be to thoroughly familiarise himself with all the properties of the particular mill's flour, formulate standards on the lines indicated, accumulate data, and generally study the whole chemical aspect of the problem before him before he makes or suggests any radical alterations. This takes time, but the work having once been done, his recommendations have the merit of being not simply speculative, but based on a reasonable degree of certainty.

Further, the introduction of the new wheel in the machinery is not keenly welcomed by those already responsible for its general running. In certain cases the present mill foremen, testing bakers and others have keenly resented what they regard as the intrusion of the chemist. It is to be feared that under such circumstances, even if no active steps are taken to nullify the recommendations of the chemist, no great amount of assistance is rendered in the direction of carrying them into effect. Much will here depend on the tact of the chemist himself, and he can do much by taking the stand that his functions are not to replace or displace those who occupied the responsible positions before him, but rather to co-operate with and assist them. It is a truism to say that the miller can make a good sack of flour, whereas the chemist *qua* chemist cannot; but if the miller and the chemist, by working heartily in unison, can make a better and cheaper sack of flour than can the former alone, then the milling chemist has justified his existence. This phase of antagonism and suspicion has to be lived down, and the chemist requires at this stage all the moral support that can be afforded him by his employer.

CHAPTER XXVIII.

CONFECTIONERS' RAW MATERIALS.

754. Flour Confectionery.—Under the general term confectionery are included articles of such a widely diversified nature, that some subdivision is necessary. It is a convenient classification to include in one group those goods of which the cake make be taken as a type, and into which flour enters as an essential constituent, and call them flour confections. The second group may then include those goods of which sugar is the basis, and which may be viewed as sugar confections. The present work attempts to deal principally with the raw materials of the first or flour group. Incidentally, some explanation will be afforded of the chemical changes underlying certain confectionery manufacturing processes.

A good deal of the matter of this chapter formed the subject of a course of Cantor Lectures delivered by one of the authors before the Society of Arts. The authors' thanks and acknowledgments are due to the Society for placing at their disposal the report of the lectures, which appeared in its Journal.

755. Flour.—The composition and properties of flour have already been dealt with so exhaustively, that but little further reference is necessary at this stage. In bread-making, the baker will naturally prefer a flour with a high absorbing power, since all else being equal, the cost of making dough with a larger percentage of water is obviously less. But with the confectioner, the moistening ingredients are in most cases more expensive than his flour, and consequently it is to his interest to use a flour which shall obtain its desired degree of moistness with the minimum of these more expensive materials. Further, the weaker and softer flours lend themselves more readily to the manipulation and working necessary, than do those of stronger nature. It should also be noted that in bread-making, the flour during the operation of fermentation undergoes considerable softening, while no similar changes occur in the manufacture of confectionery. For these various reasons, therefore, the confectioner usually selects a weak and somewhat soft flour containing much starch and comparatively little gluten, which latter should be of a soft, ductile, and silky character. For the sake of the colour of the cakes or other manufactured goods, a flour of a white or delicate creamy tint is preferred. Among flours used by the confectioner, and answering more or less to this description, are finest flours from English wheats, Hungarian flours, and those from the softer white wheats of North America.

MOISTENING INGREDIENTS.

756. Milk.—As a cake moistening ingredient, milk holds a very prominent place, and requires a somewhat extended reference. There is probably no substance of which so many analyses have been made, as milk, and consequently, its composition and variations of composition, are well known. Milk is used by the confectioner in at least three distinct forms—new milk, skim or separated milk, and sour separated milk. This latter is at times supplied mixed with butter-milk, and has special uses, to which reference will again be made. The following table, based on the authority of Vieth and Richmond, gives the average composition of pure new milk:—

Fat		4.0
Proteins	3.6	
Sugar	4.5	
Ash	0.7	
Total Non-fatty Solids		8.8
Water		87.2
		100.0

By the removal of fat the percentage of other solid bodies in milk is slightly increased, and separated milk has about the following average composition:—

Fats		0.3
Proteins	3.7	
Sugar	4.6	
Ash	0.7	
Total Non-fatty Solids		9.0
Water		90.7
		100.0

The fat of milk, like that of other fats, confers richness on cakes, and will be dealt with in detail subsequently. The sugar present in milk is a special variety, to which has been given the name of lactose. Lactose, or sugar of milk, is represented by the formula, $C_{12}H_{22}O_{11}$, and has therefore the same composition as cane sugar and maltose. It is not, however, identical with either of these bodies. Lactose differs from cane sugar in that it is far less sweet, and hence is not such a powerful flavouring agent as sugar of the latter description. The remaining constituent of milk of importance to the confectioner is the protein matter. This last has, like the white of egg, no very pronounced taste, but yet its presence confers on milk a fulness and roundness of flavour (if phraseology may be borrowed from other tasters' vocabularies) which a simple solution of lactose in water would not possess. In the baked goods, the protein of milk produces a moistness and mellowness of character, which decidedly differs from that caused by water only. Summing up, new milk gives richness through its fat, sweetness through its sugar, and what for lack of a better term, may be called "mellowness" through its proteins. Separated milk is practically new milk less its fat.

757. **Milk Standards.**—The composition of milk has been indicated in the analyses already quoted, but these figures are not by any means the lowest obtainable from undoubtedly pure samples of milk. For purposes of the Food and Drugs Adulteration Acts, the limits have been adopted of 3 per cent. of fat, and 8.5 per cent. of non-fatty solids. But for confectioners' purposes, a direct estimate of value is of more importance than knowing whether or not a particular sample of milk passes the limits of the public analyst. Thus milks containing respectively 3 and 4 per cent. of fat, would, so far as the fat is concerned, be passed as free from adulteration; but evidently the former sample has only three-fourths the fat value of the latter. For some years this subject of the valuation of milks has engaged the attention of one of the authors, who suggests, and has

for some considerable time employed a standard of valuation worked out on the following lines:—From an examination of a large number of commercial milks an average conventional standard of quality was first determined, the aim being not to go so low as the Government limit for adulteration, but to take figures which a buyer might reasonably demand to be reached in milks supplied to him. These were ultimately taken as being for

	New Milk.	Separated Milk.
Total Solids	12.5	9.3
Fat	3.5	0.3
Non-fatty Solids	9.0	9.0

The figure, 9.0, is in reality somewhat too high for the non-fatty solids of an average new milk, but in order to make the comparison between new and separated milk as simple as possible, the same figure has been adopted for each. The difference between 9.0 and the more correct figure, 8.8, does not practically affect the valuations.

At the time when these figures were adopted, the approximate wholesale prices of milk were, new 10*d.* per gallon; separated, 2½*d.* per gallon. New milk differs essentially from separated in that it contains an excess of 3.2 per cent. of fat. According to the wholesale prices this excess of fat has a market value of 7.5*d.*, and in the same proportion 3.5 per cent. of fat is worth 8.2*d.* From this the value of conventional standard samples can be expressed in terms of their constituents:—

	New Milk.	Separated Milk.
Fat	3.5 = 8.2*d.*	0.3 = 0.7*d.*
Non-fats	9.0 = 1.8*d.*	9.0 = 1.8*d.*
per gallon ..	10.0*d.*	2.5*d.*

Obviously other prices can be assigned to new and separated milks and the values of the constituents similarly calculated.

If the value of standard new milk be called 100, then the value of any other sample can from the analysis be expressed in terms of percentages of the standard from the following Table:—

VALUATION OF MILKS.

Fat in Terms of Standard.

Fat per cent.		Percentage of Standard.	Fat per cent.		Percentage of Standard.	Fat per cent.		Percentage of Standard.
0.1	=	2.34	1.7	=	39.83	3.3	=	77.32
0.2	=	4.69	1.8	=	42.17	3.4	=	79.66
0.3	=	7.03	1.9	=	44.52	3.5	=	82.00
0.4	=	9.37	2.0	=	46.86	3.6	=	84.34
0.5	=	11.71	2.1	=	49.20	3.7	=	86.68
0.6	=	14.06	2.2	=	51.55	3.8	=	89.02
0.7	=	16.40	2.3	=	53.89	3.9	=	91.36
0.8	=	18.74	2.4	=	56.23	4.0	=	93.70
0.9	=	21.09	2.5	=	58.57	4.1	=	96.04
1.0	=	23.43	2.6	=	60.92	4.2	=	98.38
1.1	=	25.77	2.7	=	63.26	4.3	=	100.72
1.2	=	28.12	2.8	=	65.62	4.4	=	103.06
1.3	=	30.46	2.9	=	67.95	4.5	=	105.40
1.4	=	32.80	3.0	=	70.29	4.6	=	107.74
1.5	=	35.14	3.1	=	72.63	4.7	=	110.08
1.6	=	37.49	3.2	=	74.98	4.8	=	112.42

Non-fatty Solids in Terms of Standard.

Non-Fatty Solids per cent.	Percentage of Standard.	Non-Fatty Solids per cent.	Percentage of Standard.	Non-Fatty Solids per cent.	Percentage of Standard.
4.8 =	9.6	6.4 =	12.8	8.0 =	16.0
4.9 =	9.8	6.5 =	13.0	8.1 =	16.2
5.0 =	10.0	6.6 =	13.2	8.2 =	16.4
5.1 =	10.2	6.7 =	13.4	8.3 =	16.6
5.2 =	10.4	6.8 =	13.6	8.4 =	16.8
5.3 =	10.6	6.9 =	13.8	8.5 =	17.0
5.4 =	10.8	7.0 =	14.0	8.6 =	17.2
5.5 =	11.0	7.1 =	14.2	8.7 =	17.4
5.6 =	11.2	7.2 =	14.4	8.8 =	17.6
5.7 =	11.4	7.3 =	14.6	8.9 =	17.8
5.8 =	11.6	7.4 =	14.8	9.0 =	18.0
5.9 =	11.8	7.5 =	15.0	9.1 =	18.2
6.0 =	12.0	7.6 =	15.2	9.2 =	18.4
6.1 =	12.2	7.7 =	15.4	9.3 =	18.6
6.2 =	12.4	7.8 =	15.6	9.4 =	18.8
6.3 =	12.6	7.9 =	15.8	9.5 =	19.0

In the next Table are given the results of analysis of some typical examples of milk, their values in terms of standard and per gallon, assuming standard milk to be worth 10*d.* per gallon.

Attention is drawn to the fact that milk No. 7, although of highest value in terms of standard, shows, nevertheless, evidence of having been watered, and would probably be made the subject of a prosecution if analysed for the purposes of the Foods and Drugs Acts. The public analyst is concerned simply with adulteration, while the commercial user is more vitally interested in the question of actual value.

A gallon of milk weighs approximately about 10.3 lbs. or 10 lbs. 5 ozs., and if this be bought at 10*d.*, the purchaser gets, if the milk is of standard value, 0.36 lbs. = 5.76 ozs. of butter fat, for which he pays 8.2*d.*, or at the rate of 22.7*d.* per lb.; and 0.93 lbs. = 14.88 ozs. of mixed protein, milk-sugar, and ash; for which he pays 1.8*d.*, or at the rate of 1.9*d.* per lb.

A gallon of separated milk of standard value weighs about 10.5 lbs. or 10 lbs. 8 ozs., and if this be bought at 2½*d.*, the purchaser gets 0.03 lbs. = 0.48 ozs. of butter fat and 0.945 lbs. = 15.1 ozs. of mixed protein, milk-sugar, and ash, making 0.975 lbs. of total solids, which he buys at the rate of 2.56*d.* per lb.

Taking butter, containing 87 per cent. of butter fat, at 1*s.* per lb., then—

One gallon of separated milk, costing	2½*d.*
And 0.33 lbs. of butter, costing	4½*d.*
Together costing	7*d.*

will yield the equivalent in quantity of the total non-fatty solids and butter-fat of one gallon of new milk costing 10*d.*

758. **Condensed Milk.**—Condensed milks of the unsweetened variety are at times employed instead of new or separated milks. In ascertaining the value of these, it is well to dilute them to three times thir original volume. Then such a milk as No. 9 is, as nearly as possible, of the same degree of concentration as standard milk. One gallon of such milk, in the concentrated form, is worth, as against standard milk

9.8 × 3 = 28.4*d.* per gallon.

No.	Description of Milk.		Composition.	Value in terms of Standard.	Value per Gallon.
1	Milk with 26 per cent of added water	Fat	3.2	74.98	
		Solids not fat	6.6	13.20	
			9.8	88.18	8.8*d.*
2	Milk deprived of 40 per cent of its cream	Fat	1.8	42.17	
		Solids not fat	9.1	18.20	
			10.9	60.37	6.0*d.*
3	Old Somerset House limit, below which milks were considered adulterated	Fat	2.5	58.57	
		Solids not fat	8.5	17.00	
			11.0	75.57	7.5*d.*
4	British Government limit	Fat	3.0	70.29	
		Solids not fat	8.5	17.00	
			11.5	87.29	8.7*d.*
5	Authors' conventional standard ..	Fat	3.5	82.00	
		Solids not fat	9.0	18.00	
			12.5	100.00	10.0*d.*
6	Average composition of pure new milk	Fat	4.0	93.70	
		Solids not fat	8.8	17.60	
			12.8	111.30	11.1*d.*
7	Very rich milk slightly watered ..	Fat	4.3	100.72	
		Solids not fat	8.1	16.20	
			12.4	116.92	11.7*d.*
8	High quality sample of skimmed milk	Fat	0.4	9.37	
		Solids not fat	9.1	18.20	
			9.5	27.57	2.76*d.*
9	Unsweetened condensed milk diluted to three times its volume	Fat	3.5	82.00	
		Solids not fat	8.2	16.40	
			11.7	98.40	9.8*d.*
10	Unsweetened condensed milk diluted to three times its volume	Fat	2.0	46.86	
		Solids not fat	8.6	17.20	
			10.6	64.06	6.4*d.*

No. 10 has been deprived, before condensing, of nearly half its fat, and consequently is only worth

$$6.4 \times 3 = 19.0d. \text{ per gallon.}$$

Such condensed milks may not only be diluted and used as moistening agents, but also at times are employed in their concentrated state, as a more or less complete substitute for butter. These condensed milks have, or should have, an approximate density of 1.1, and therefore a gallon of No. 9 will weigh about 11 lbs., and is worth, on the milk standard, 28.4*d.* or 2.58*d.* per lb. A gallon of the milk will contain, roughly, 2.70 lbs. of non-fatty solids, and 1.15 lbs. of butter fat. This is the equivalent in quantity of 2.85 gallons of separated milk, at a cost of 7.1*d.*, and 1.32 lbs.

of butter which at 1*s.* per lb. costs 15.8*d.*, or a total of 22.9*d.* Unless, therefore, such full value milk as No. 9 is bought at 2.08*d.* per lb., its proteins, milk-sugar and fat, can be more cheaply supplied from separated milk and butter.

759. Milk Powders.—By modern processes, milk is now reduced to the condition of a dry powder, and is an article of sale containing only a very small percentage of moisture. Full cream, half cream, and separated milk powders are now on the market. In the absence of moisture, these bodies have the following approximate composition:—

COMPOSITION OF MILK POWDERS.

Constituents.	Full-cream.	Half-cream.	Separated.
Fat	31.2	17.2	3.2
Proteins	28.1	34.0	39.8
Sugar	35.2	42.3	49.5
Ash	5.5	6.5	7.5
	100.0	100.0	100.0
Weight of water required to convert 1 lb. of each into liquid of the same strength as milk	7.8 lbs.	9.3 lbs.	10.7 lbs.

One pound of the full-cream powder is equivalent in butter value to about 5¾ ozs. of butter; in addition to which it contains proteins and sugar in approximately the same quantities. On mixing the powders with warm water in the proportions given above, a fluid corresponding to the original milk is produced.

760. Eggs.—Next to milk, eggs are one of the most important moistening agents to the confectioner. The raw white of egg is a viscous glairy liquid, the yolk being somewhat more fluid in character. In composition, the white of egg consists of protein matter dissolved in water, while the yolk contains in addition to protein, fat and colouring matter. The following table gives respectively the results of analysis of the white, yolk, and whole interior of the egg:—

Constituents.	White.	Yolk.	White and Yolk together.
Water	85.7	50.9	73.7
Protein	12.6	16.2	14.8
Fat	0.25	31.75	10.5
Ash	0.59	1.09	1.0

The white of egg may be viewed as a solution of one part of albumin in seven parts of water, while in the whole egg about two-fifths of the solids consist of fat, and three-fifths of protein matter. The water of the whole egg amounts roughly to three-quarters of its weight. Or putting it another way, 1 lb. of whole eggs contains about 4 ozs. of solids, and 1 lb. of white of egg just half that quantity or 2 ozs. When either of these are used in making a dough with flour, the water part of the egg does the moistening, and acts in the same way on the constituents of flour as water alone would do. The white, if used alone, is so nearly tasteless that it cannot be said to confer any very decided flavour; but, as was remarked with regard to the protein matter of milk, it imparts the property described as that of mellowness to goods in whose manufacture it is used. The yolk, on the other hand, is very marked in flavour, and just as eggs themselves are in consequence most pleasant eating, so cakes have a remarkable richness of flavour caused by the yolks of eggs used in their manufacture.

The yellow of the yolk confers its distinctive colour on the cakes and other goods in which it is employed; as a consequence the full yellow of a cake has become associated with the idea of its richness. With cakes made at very low prices, the use of eggs in full proportion becomes an economic impossibility, and therefore, in the cheaper cakes, an effort is made to please the eye by adding artificial colouring matter. The nature and composition of the substances used for this purpose are described in a subsequent paragraph.

761. Dried Egg Whites.—For certain purposes, in place of the white of eggs, the confectioner has offered to him such whites as desiccated albumin. This preparation should consist of the pure white of egg evaporated down to dryness at a temperature well below that of the coagulation or setting of albumin. Such dried albumin should soften on the addition of water and form a solution possessing the same properties as fresh white of egg. The solution should be free from any unpleasant taste or odour of decomposition. As white of egg contains one-eighth its weight of pure albumin, it follows that dried egg-albumin should, everything else being equal, be worth weight for weight eight times as much as fresh white of egg. In other words, pure egg-albumin at anything below eight times the cost of white of egg is economically to be preferred to such fresh whites. The objections to such commercial albumin are first, that it may be partly coagulated, and second, that it may be unpleasant in odour or taste either as the result of preparation from unsound eggs, or incipient putrefaction during its manufacture. Among adulterants, to which dried egg-whites are subject, are dextrin, sugar, and gelatin. Serum- or blood-albumin, is less expensive than egg-albumin, and so may possibly be substituted for it without declaration to the purchaser.

The table on the following page gives the results of analysis of a number of samples of dried egg-whites, together with that of fresh white of egg taken for comparison. A 5 per cent. solution of the powdered albumin in cold water was prepared and filtered through paper. The total solid matter, and nitrogen by Kjeldahl's method, were determined on the filtrate. Another portion of the filtrate was acidulated with acetic acid, and boiled so as to coagulate the albumin, which was in turn filtered off. The residual soluble matter and nitrogen were then determined in the second filtrate. In each case the nitrogen multiplied by the factor 6.25 gave a quantity which did not amount to as much as the total matter present. The difference is therefore returned as non-nitrogenous matter.

The samples 1, 2, and 3 were specimens of commercial dried egg-whites: A was the white of fresh egg, and AA the results of the same analysis calculated to what they would have been on the same white dried to a water-content of 15 per cent., *without* other change.

The fresh white of egg was diluted to about the same degree of concentration as the 5 per cent. solution before analysis. While the fresh egg-white was perfectly soluble, the dried albumins contained insoluble matter varying from 5.70 to 10.72 per cent. This is probably albumin which had been coagulated in drying, as the total nitrogenous matter is quite up to the normal amount. The insoluble matter and coagulated albumin together agree very fairly with the coagulated albumin of AA. The protein matter, which remains uncoagulated under the conditions of the experiment is practically the same in all samples. The non-coagulated non-nitrogenous matter in the egg-white is more than is usually given, and cannot be accounted for by assuming the factor used for proteins to be too low. It will be seen that the amount is practically the same in all the samples. Adulteration with sugar or dextrin would materially increase this figure, while the addition of gelatin would augment the non-coagulated nitrogenous matter. The whole of these three samples may be regarded as genuine, but in the act of drying varying amounts of proteins have been rendered insoluble.

Constituents.	1.	2.	3.	A.	AA.
Water	18.10	15.08	15.08	87.55	15.00
Insoluble Matter	5.70	6.52	10.72	0.00	0.00
Coagulable True Albumin	52.86	52.27	52.26	8.92	61.90
Associated Non-nitrogenous Matter	4.54	4.53	2.54	0.56	3.93
Non-coagulated Nitrogenous Matter, as Proteins	7.74	8.15	7.62	1.15	7.98
Non-coagulated Non-nitrogenous Matter	11.06	13.45	11.78	1.62	11.22

762. Moistening Effect of Fat.—Before altogether passing from moistening action, mention may be made of the moistening effect of melted fat, as butter or lard. Such moistening is quite different in character from that of substances whose essential moistening constituent is water. The latter all affect the gluten of flour, and produce a dough such as is used in making bread; the former makes a moist mass, devoid altogether of any tenacity, but, instead of that, distinctly "short." As an example of the use of butter fat as a moistening agent Scotch shortbread may be mentioned.

763. Glycerin.—In another sense of the word "moistening," glycerin must be referred to as one of the confectioners' moistening agents. Glycerin is well known as a colourless, odourless, and viscous liquid, of a very sweet taste. Its chemical composition and properties are described in paragraph 105. If exposed to the air, glycerin increases in volume through absorption of moisture. When used in small quantities in cakes, the result is that drying is much retarded, and the cake remains moist and fresh for a considerable time longer than would otherwise be the case. As glycerin is without injurious effect on the human economy, its use in this direction may be regarded as perfectly harmless.

AERATING INGREDIENTS.

764. Aerating Agents.—A number of these bodies, such as bicarbonate of soda, cream of tartar, tartaric acid, and similar substances have already been fully described in Chapter XVII., paragraph 512.

765. Aerating Action of Eggs.—It is well known that, under certain circumstances, eggs are valuable lightening agents, yet they do not give off any gas whatever within the range of temperature employed by the confectioner, neither do they cause evolution of gas from any other ingredients he is in the habit of using. In these particulars they differ markedly from the aerating agents before referred to, and their action must consequently be looked for in some other direction. First of all, eggs, and especially their whites, have a peculiar glairy consistency. In virtue of this, if eggs be present in a mixture, any air incorporated with it prior to baking is retained much more tenaciously. Consequently, when the goods are placed in the oven, such air expanding with increase of temperature, increases the volume of the articles by its more perfect retention, as a result of the peculiar viscous and binding nature of the egg-albumin. Another valuable property of eggs, so far as this effect is concerned, is that of setting or coagulation. Just as in being boiled, the egg matters become solid during the act of baking: as the temperature of coagulation is reached they begin to set, and so fix the dough, so to speak, in its expanded state. The lightening function of eggs is therefore summed up in the statement that they do not of themselves evolve or cause the evolution of gas, but assist in its retention when developed by the expansion of air, or obtained from any other gaseous source.

ENRICHING INGREDIENTS.

766. Fats.—The next step to be considered is that of enriching a cake, an operation which is performed by the addition and incorporation of fat. Scotch shortbread dough is an instance of dough made with fat as a moistening agent. The dough itself is short and non-coherent, while the baked shortbread is extremely rich in flavour and character. As fats fulfil so important a function, it becomes necessary to inquire into the properties of the bodies embraced under this general heading of fat. Reference has already been made in Chapter V. to the composition and some of the properties of fats, but at this stage a somewhat more extended description is advisable.

Under this name are included a number of substances, both of animal and vegetable origin. The fats have various melting temperatures and, speaking broadly, those which are solid at the ordinary temperature are called "fats," while those which under this condition are liquid receive the name of "oils." Pure fats and oils are usually either colourless or of a faint yellow tinge, while some of vegetable origin possess a green tint, derived from green vegetable colouring matter. Many fats and oils possess a distinct smell and taste, agreeable or otherwise, and indicative of their origin; such characters appertain, however, to minute traces of associated impurities, rather than to the pure fat and oil itself. Consequently, the act of refining and purifying oils generally tends to deprive them of special flavour, leaving behind a bland and almost tasteless body. All ordinary fats and oils possess the property of "greasiness"; if dropped in the liquid state on paper or cloth, they produce a grease spot, and give that well-known "slipperiness" so characteristic of a greased surface.

Oils and fats are practically insoluble in water, somewhat soluble in absolute alcohol, or even strong spirit, especially when hot. Ether, chloroform, light petroleum or petroleum spirit, and other somewhat analogous substances dissolve them readily; so also the various oils and fats are readily soluble in each other, and consequently may easily be mixed in all proportions. Viewed themselves as solvents, they have practically no action on most of the substances employed by the confectioner. Thus the constituents of flour are not dissolved by oil, and this is the reason of the particular "shortness" of flour mixtures, such as shortbread dough, into which any fat has largely entered. Oil dissolves some colouring matter, and also flavourings, so that these amalgamate somewhat readily with the fatty part of various mixtures.

Fat and oils, if preserved from the atmosphere, remain unchanged for a considerable time, but on exposure are liable to acquire the property of rancidity. This is much hastened by the presence of impurities resulting from imperfect separation from the animal or vegetable source of origin. Natural fats may be viewed as compounds of the higher fatty acids with glycerin, or some closely allied body. Among the fatty acids most frequently occurring are those of the stearic series, represented by the general formula $HC_nH_{2n-1}O_2$, and the oleic series represented by $HC_nH_{2n-3}O_2$. Thus mutton fat is largely composed of stearate of glycerin, which body may be artificially produced by heating together glycerin and stearic acid thus,

$$\underset{\text{Stearic Acid.}}{3HC_{18}H_{35}O_2} + \underset{\text{Glycerin.}}{C_3H_5(HO)_3} = \underset{\text{Glycerin Stearate.}}{C_3H_5(C_{18}H_{35}O_2)_3} + \underset{\text{Water.}}{3H_2O}.$$

This body, glycerin stearate, is conveniently called "stearin."

Olive and lard oils consist largely on the other hand of glycerin oleate: the formula of oleic acid is $HC_{13}H_{33}O_2$, and the oleate is consequently $C_3H_5(C_{18}H_{33}O_2)_3$. This body has received the name of "olein."

Stearin is a somewhat hard solid, while olein is liquid at ordinary temperatures; as may be surmised, therefore, stearin and allied bodies are more largely found in fats, while oils consist principally of olein and its congeners.

767. **Melting and Solidifying Points.**—The temperatures at which these changes occur are of considerable importance in the selection of fats for different purposes; a fat when once melted remains liquid at a considerably lower temperature than that required for the act of fusion. Thus mutton fat melts at a temperature ranging between 46.5 and 47.4° C.; but when once melted only re-solidifies at a temperature of from 32 to 36° C. In the table following later, the temperatures of solidification are given. At temperatures varying from 250° C. (482° F.) to 300° C. (572° F.), fats are decomposed, yielding various products of a disagreeable odour.

768. **Specific Gravity of Fats.**—These bodies are all of them lighter than water, the specific gravity varying between 875 and 970, water being taken at 1000. The specific gravity is a valuable means of identifying and distinguishing fats, and consequently has been determined with considerable care. As the oils are liquid at ordinary temperature, and the fats solid, it is preferable to select some temperature at which all are in the liquid state. That found most generally convenient is the temperature caused by immersion in boiling water, and this in practice registers at 99° C. The figures given in the subsequent table have been taken at this temperature; they are somewhat abnormal, as they give the specific gravity of the fats at 99° C. compared with water at 15.5° C.

769. **Chemical Constants of Fats.**—There are various data used by the chemist in recognising different fats, and detecting adulterations. Among these are the following:—

770. **Iodine Value.**—This term is applied to a most important determination now made on fats as the result of investigations by Hubl. If any fat or oil be dissolved in chloroform, and then an excess of a solution of iodine and mercury chloride in alcohol added, absorption of the iodine by the fatty matter proceeds. Using proper precautions, the amount of iodine so absorbed is capable of very exact measurements, and the figure thus obtained is that quoted as the "iodine value." Thus, if the iodine value of a fat is given as 50, this means that under the standard conditions of what is known as Hubl's test, 100 parts of that fat absorb 50 parts of iodine. The iodine value not only throws light on the probable nature of an oil or fat, but also, in many instances, affords valuable inditions of the purity and quality of the fat in question. Speaking generally, the more oily a fat, the higher is its iodine value.

771. **Reichert-Meissl Value.**—Fats have already been referred to as compounds of fatty acids. Of this group of bodies some are readily volatile at the temperature of boiling water, while others are non-volatile under the same conditions. Butter fat is distinguished from almost all other fats by containing a high proportion of such volatile acids. The exact determination of the volatile acids in a fat is a work of tediousness

and some difficulty. But under standard conditions, a fairly constant fraction of such volatile acids can be obtained and determined, and this constitutes a test of considerable importance. A weighed quantity, 5 grams of the fat, is made into a soap, by treatment with excess of potash; on adding excess of sulphuric acid, this soap is decomposed, and the whole of the fatty acid liberated. The solution is altogether diluted with water to 140 cubic centimetres, and then distilled until 110 cubic centimetres of the distilled liquid have been collected. The acidity of this filtered distillate is then determined by the use of phenolphthalein and decinormal potash solution. Such acidity is termed the Reichert-Meissl value. Thus, if 5 grams of butter fat gave a distillate, which took 30 cubic centimetres of decinormal potash to render it neutral, then the Reichert-Meissl value of such fat would be said to be 30. This figure is evidently the measure of the quantity of volatile acid which distils over under certain standard conditions.

772. Butyro-Refractometer Value.—Like other transparent substances, melted fats have a refractive action on a ray of light passing obliquely through a layer of them. The amount of such refraction is fairly constant for some fats, but varies however with the temperature. The instrument known as Zeiss' butyro-refractometer is one for rapidly measuring the amount of such refraction. On looking through the optical portion of such an instrument, the point of refraction is shown by means of a scale, and can be read off at once into degrees, which, for example, may be called 47°. The instrument is also provided with a thermometer, graduating into arbitrary degrees, and this is also read at the same time as the point of refraction of the fat. Suppose that this figure is also 47°; then in the case of a butter for which this determination is principally used, the difference between the two is 0°, and such butter fat is at the bottom limit of an arbitrary scale of purity. If the reading on the butter fat is lower than that of the thermometer, then the butter so far as this test goes is passed as pure: if higher, then the butter is suspicious, and requires to be further and more systematically tested. The following figures were obtained during actual examination of various butters:—

Butter reading	46.4	44.0	50.0	52.5
Thermometer reading	47.0	45.9	47.1	47.1
	—0.6	—1.9	+2.9	+5.4

Of these tests, the two former were pure butters, the third was a margarine, and the fourth a beef-fat preparation. By means of the arbitrarily marked thermometer, the disturbing influence of temperature is eliminated, as minus results indicate purity of butter fat, and plus results impurity. Otherwise it becomes necessary to give both the butter readings and the temperature of the fat when it was taken, after which such readings must be calculated and corrected to a given temperature. Thus at 25° C. genuine butters have a range of from 49.5 to 54.0°, and margarines of from 58.6 to 66.4°.

773. Tabular Description of Oils and Fats.—In the table on the following page particulars are given of the various fats and oils either directly used by the confectioner or indirectly as component parts of various butter substitutes or other confectioners' fats. For these data and their arrangement the authors are indebted to Allen's *Commercial Organic Analysis,* and Lewkowitsch's *Analysis of Oils and Fats.*

PROPERTIES OF OILS AND FATS.

Kind of Oil or Fat.	Source.	Specific Gravity at 99° C.	Solidifying Point °F.	Iodine Value.	Reichert-Meissl Value.	Butyro-refractometer Value at 25° C.	General Properties.
Olive Oil	Fruit of olive	861.5	21 to 39	83.0	0.6	62.4	Pleasant flavour; easily turns rancid.
Almond oil	Nuts of almond	919 at 15° C.	—4 to +14	98.4	—	64.4	Bland, agreeable taste.
Earth nut oil	Nuts of arachis	867.3	23	103	—	65.8	Yellow, or nearly colourless; pleasant nutty flavour. Used as adulterant of olive and lard oils, and in margarines.
Cotton-seed oil	—	872.5	34 to 50	106	—	68	When refined, of straw or golden yellow colour. Bland, agreeable taste. Used in margarine and butter substit'ts.
Maize oil	Maize germ	—	—4 to +14	115	0.66	—	Yellow; thicker than olive oil.
Sesamé oil	Seeds of sesamum	867.9	21 to 25	106	1.2	68	Pale yellow, odorless, agreeable taste. Used in margarine.
Hazelnut oil	Nuts of hazel	—	—2 to +14	86	0.99	—	Light yellow; mild, sweet taste, somewhat resembles butter. No marked smell. Soon becomes rancid.
Lard oil	Obtained by pressing lard	—	25 to 50	67 to 82	—	—	Very slightly coloured; slight odour of lard.
Poppy-seed oil	—	873.8	—18	138	—	73	Straw yellow, limpid, odourless; much resembles olive oil.
			Melting point				
Cacao butter	Nuts of theobroma	857.7	86 to 93	34.3	3.2	47 at 40° C.	Colourless; chocolate-like taste and smell. Not liable to rancidity.
Nutmeg butter	—	898	77 to 93	41.5	—	—	Taste and odour of nutmeg.
Shea butter	—	859	73 to 110	56.5	—	—	Faint cacao-like odour and agreeable flavour.
Cotton seed stearin	From cotton seed oil	868.4	70 to 104	89	—	—	Resembles tallow; used for adulterating lard and in margarine.
Cocoa-nut oil	Nuts of cocos	873.6	68 to 82	8.7	7.5	35.5 at 40° C.	White, or slightly coloured; tastes of cocoa nut; readily turns rancid.
Tallow; suet	From the ox or sheep	862.6	97 to 120	35 to 40	0.5	49 at 40° C.	Melting point varies with part and nature of animal from which derived.
Lard	From abdomen and other parts of the hog	860.8	83 to 113	46 to 63	Below 1.10	56 to 58 at 25° C. 45 to 53 at 40° C.	Melting point varies much with part of animal from which derived. Used in butter substitutes.
Horse fat	From the horse	861	93 to 129	71 to 86	1.6 to 2.1	53.7 at 40° C.	Yellow or dirty white to brown, consistency of lard, or harder. Said to be used in butter substitutes.
Butter fat	Cow's milk	867.7	84 to 95	26 to 35	24 to 33	49.5 to 52.5 at 25° C. 41 to 44 at 40° C.	Yellow; pleasant taste and smell.
Margarine	Beef oleo, neutral lard, and various vegetable oils	859.2	93 to 104	48 to 55	1.1 to 2.2	48.6 to 49 at 40° C.	Closely resembles butter, with which it is frequently mixed

774. Butter.—There can be little doubt that where prime cost is no object, butter is by far the best and most pleasant fat to be used for the great majority, if not all, of confectioners' purposes. Substitutes for butter will succeed or fail according to the degree in which they reproduce and possess the characteristics of good butter. Butter is therefore first described, and other substances which follow are naturally compared with and tested against butter as a standard.

Butter may be defined as the substance produced by churning the cream derived from milk. During this process the fat globules coalesce, and after washing and other treatment, result in the production of butter.

The British sources of butter supply include Ireland, France, Denmark, Siberia, Canada, Australia, and New Zealand. The last of these devotes very special care to its export trade. All butter for export purposes is graded by the State, which in the first place classifies and keeps a register of all dairies. The Government provides cold storage rooms at specified ports, in which the butter is deposited while awaiting shipment. The graders, who are as a rule picked dairy factory managers, examine each parcel, and give points on the following scale, for creamery butter:—

	Points.
Flavour	50
Body, moisture, texture	25
Colour	10
Salting	10
Finish	5
	100

Butter is placed in the first grade, which secures 88 points and over; in the second grade, under 88 points, and over 80 points; and in the third grade, with 80 points and under. Of creamery butters examined and graded in 1899-1900, the following results were obtained:—

First grade	92.63 per cent.
Second grade	7.10 „
Third grade	0.27 „

Another part of the duties of the port graders is to inspect the cold storage accommodations of ships, and in this way to do all they can to see that such produce has a good send-off from colonial shores. Its well-being in this country is attended to by the Produce Commissioner, who sees that all is well on arrival here, notes critically any defects, and reports them to New Zealand for remedying in the future. It has been thought well to thus explain in detail the organised precautions taken to ensure for this country a supply of the finest possible colonial butter.

775. Composition of Butter.—However well and carefully made, butter contains a good deal else than pure fat; among such other matters being water, proteins, and milk-sugar—usually classed together in analysis as curd, traces of natural mineral matter, and more or less added salt. For confectioners' purposes the water is useless. The presence of large quantities of curd in butters is general evidence of inefficient manufacture, and excess of protein matters by their rapid alteration confers an unpleasant cheesy taste. Salt is added as a preservative, and also as a flavouring agent; but as such is of no service to the confectioner, who, as a matter of fact, when using a salt butter, will usually wash the salt out as completely as possible as a preliminary to its employment. The user is thus reduced to the fat, and practically that is the substance in butter of value: everything else being equal, the greater the proportion of fat the more valuable is the butter.

A reference to the table already given will show that butter differs from every other fat quoted in the very high Reichert-Meissl value it possesses. As already explained, this figure is an indication of the amount of volatile fatty acids present. These substances give butter those characteristic properties not exhibited by any other fat. Therefore, the determination of Reichert-Meissl value is, in the case of butters, a most important estimation. In the table below, Composition of Butter and Margarine, are given the results of analyses of various typical butters which, except when otherwise stated, have been made by the authors.

Samples Nos. 6 to 12 are fair average samples, and not in any way picked or choicest butters of their kinds. Looking at the whole series, the New Zealand butters are characterised by containing the lowest percentage of water, and highest of butter fat. The Canadians and Australians also are very low in water, while next follow the Siberian samples. The Irish butters are marked by a large percentage, both of water and salt.

The Reichert-Meissl value of the butters varies from about 26 to over 31; the whole of these figures being within the recognised limits of purity. But evidently a butter with a value of 31 must be richer in volatile acids than is one with 26, and will be found, if the term may be coined, to be the more "buttery" butter of the two. In confectioners' valuation of butter, a high Reichert-Meissl value is of importance since the fullness of butter flavour indicated will enable such a butter to be mixed with a considerable proportion of a neutral character fat, such as lard, and yet be as "buttery" in character as another butter containing normally a low proportion of volatile fatty acids.

776. Butter Standards.—One of the data given, it will be noticed, is the value in percentage of "Standard." Taking these butters right through, it was found that many samples contained 87 per cent., or over, of butter fat. This figure 87 was accordingly taken as a standard for butter. In the following table is given, in column two, the value, in

VALUATION OF BUTTERS.

Percentage of Fat.	Value in Terms of Standard.	Quantity containing same weight of Fat as 100 lbs. of Standard.
70	80.4	124.3
71	81.6	122.5
72	82.7	120.8
73	83.9	119.1
74	85.0	117.5
75	86.2	116.0
76	87.3	114.4
77	88.5	112.9
78	89.6	111.5
79	90.8	110.1
80	91.9	108.7
81	93.1	107.4
82	94.2	106.0
83	95.4	104.8
84	96.5	103.5
85	97.7	102.3
86	98.8	101.1
87	100.0	100.0
88	101.1	98.8
89	102.3	97.7
90	103.4	96.6
91	104.6	95.6
92	105.7	94.5
93	106.8	93.5
94	108.0	92.5
95	109.2	91.5

ANALYSIS OF SAMPLES OF BUTTER AND MARGARINE.

No. Mark or Description.
1. English, analysis by Richmond.
2. German, salt ,, ,,
3. Danish, salt ,, ,,
4. Swedish, salt ,, ,,
5. Australian, salt ,, ,,
6. Danish.
7. Normandy, fresh.
8. Normandy, salt.
9. Canadian (I.).
10. Canadian (II.).
11. Australian.
12. New Zealand.
13. Irish, lowest in water of nine samples.
14. Irish, average of nine samples.
15. Irish, highest in water of nine samples.
16. Siberian, lowest in water of ten samples.
17. Siberian, average of ten samples.
18. Siberian, highest in water of ten samples.
19. New season New Zealand, lowest in water of nine samples.
20. New season New Zealand, average of nine samples.
21. New season New Zealand, highest in water of nine samples.
22. Margarine, with admixture of butter.
23. Margarine (II.) ,, ,,
24. Margarine (III.), without butter.

COMPOSITION OF BUTTER AND MARGARINE.

No.	Water.	Salt.	Curd (chiefly Casein).	Fat.	Total.	Value in percentage of "Standard."	Reichert-Meissl Value.	Butyro-refractometer Value.
1	11.6	1.0	0.6	86.8	100.0	89.6	—	—
2	12.3	1.3	1.2	85.2	100.0	97.9	—	—
3	13.4	1.9	1.3	83.4	100.0	95.8	—	—
4	13.8	2.0	1.3	82.9	100.0	95.3	—	—
5	12.7	1.6	1.2	84.5	100.0	97.0	—	—
6	12.4	1.4	0.6	85.6	100.0	98.3	32.3	—1.9
7	12.4	0.0	1.7	85.9	100.0	98.7	31.1	—1.2
8	10.6	1.4	0.8	87.2	100.0	100.2	31.1	—1.0
9	9.7	1.5	0.6	88.2	100.0	101.3	28.6	—0.05
10	8.2	1.7	0.3	89.8	100.0	103.3	28.9	+1.1
11	11.8	3.4	0.4	84.4	100.0	97.0	31.0	—1.2
12	9.1	2.8	0.5	87.6	100.0	100.6	29.8	—0.2
13	14.5	4.6	0.9	80.0	100.0	91.9	30.8	—
14	16.7	6.2	1.1	76.0	100.0	87.3	31.1	—
15	19.8	7.1	1.0	72.1	100.0	82.8	31.6	—
16	9.4	1.0	0.8	88.8	100.0	102.0	27.1	—
17	10.3	1.4	1.1	87.2	100.0	100.2	26.7	—0.5
18	11.3	1.2	1.2	86.3	100.0	99.1	26.9	—
19	7.2	1.2	0.4	91.2	100.0	104.8	31.9	—0.2
20	7.6	1.2	0.4	90.8	100.0	104.3	—	—
21	8.1	0.9	0.3	90.7	100.0	104.1	30.4	+0.9
22	13.2	1.7	3.0	82.1	100.0	94.3	5.7	+2.9
23	7.7	1.7	0.7	89.9	100.0	103.1	4.0	—
24	6.7	2.3	0.2	90.8	100.0	104.2	0.8	+5.4

terms of the standard, of butters containing various percentages of fat. Also it is shown in column three how many pounds of the butter are required to yield the same amount of fat, as do 100 pounds of the standard butter.

Thus supposing that a butter has only 72 per cent. of fat, then everything else being equal, it is only worth 82.7 per cent. of butter of standard composition. Further, in use 120.8 lbs. of that butter are required to go so far in fat as do 100 lbs. of the standard. Taking on the other hand a butter with 92 per cent. of fat, such butter is worth 105.7 per cent. of standard, and in use 94.5 lbs. only are required to go so far as 100 lbs. of the standard.

777. Weak and Strong Butters.—In working butters, there is one point which may always be noted. Some butters are defined as weak, while others are strong and waxy. The former, on warming, readily become oily, while the latter remain tough and wiry. If paste be made from the former, the paste does not rise well, while the melted fat drains readily from the hot goods. The tougher butters make lighter paste, and more fully retained by the articles when baking.

Prior to use in confectionery, butter is usually "creamed"; in this operation the butter is beaten until of the consistency of cream. The operation is hastened by slightly warming, although except in very cold weather such is not absolutely necessary. This act of creaming consists of breaking down the butter into an emulsion in which both the fat and the water exist in minute globules.

778. Rancidity.—A word may here be said as to rancidity in butters; and on this point some interesting data are given by Lewkowitsch, of which the following is a summary. When kept under unfavourable conditions, butter acquires a strong acrid unpleasant flavour, to which the name of rancidity is given. At the same time, some decomposition of the fat goes on, and part of the fatty acids is liberated in the free state. This alone does not, however, produce rancidity, since the addition of free fatty acid to an oil does not impart a rancid character, although it gives the oil a sharp taste. It has been surmised that bacteria are responsible for the production of rancidity, but this has been disproved. Neither is the presence of moisture necessary, since dried fats are more liable to this change than those containing a certain amount of moisture. Rancidity must therefore be considered due to direct oxidation by the oxygen of the air, this action being intensified by exposure to light. Both oxygen and light must act simultaneously, in order to produce rancidity, either of these agents alone being unable to cause any alteration in that respect. Solid fats, especially those of animal origin, are less liable turn rancid than liquid fats. With an indication of the causes of rancidity, the means of prevention will suggest themselves to the user of fats.

779. Beef Fat.—This is sometimes found in the well known form of dripping, but does not by itself reach the confectioner in any great quantity. When the very fatty portions of the carcase are heated, the fat melts, and separates from the containing tissues, and in this way a pure beef fat may be obtained. Like many other animal fats—that of beef is a mixture of a harder and a softer portion. If the fat be gently heated, the softer part becomes liquid, while the harder part still retains its solidity. The fat in this condition may be enclosed in canvas bags, and subjected to pressure: the more liquid portion passes through and constitutes a body known in commerce as "oleo," while the harder part remains behind, and commercially is termed "beef stearin."

780. Hog Lard.—Lard is obtained from the fat of the pig in much the same way as beef fat from that of the ox. Lard is a white fat of somewhat pleasant taste and a soft consistency. Like beef fat, it may be separated by warmth and pressure into lard stearin and lard oil. The fat of some portions of the pig is much harder than the others, consequently, some of the fat of the abdomen, if melted down separately, gives a much harder lard than do other parts, or than would be yielded by the fat of the whole animal. The harder lards are found to contain a larger proportion of stearin than do those of softer nature. In summer and very hot weather there is considerable difficulty in cooking with the softer lards, which become almost liquid. In order to get over this, such lards may be fortified by the addition of stearin of either lard or beef fat. Given a soft whole hog lard, there can be little doubt that its cooking properties are improved by the addition of stearin, while certainly the wholesomeness is in no way deteriorated. The only point is, that a purchaser who gives the price for the more expensive lard, derived from the harder parts of the pig, has a right to expect to obtain the same, and not a soft whole lard, hardened by some foreign fat. Lards are, at the present time, almost pure fats; they melt into a liquid, which is either perfectly clear, or only slightly turbid through the presence of a scarcely weighable quantity of unseparated tissue. The chemist, in analysing lard, directs his attention principally to the detection of foreign fats or oils. In doing this, the iodine value is of much assistance to him; the harder fats, as beef stearin, having a lower value than lard, while most oils have a much higher value. The difficulty here is that a mixture of beef stearin and oil may be so arranged as to have the same iodine value as pure lard. The microscope is called into requisition in order to detect the addition of stearin, since in samples of lard dissolved in ether, and then allowed to recrystallise out, the crystals from beef stearin differ in appearance from those of lard in a state of purity. These crystals are not only microscopically examined, but also separated and weighed. Unfortunately, these tests at times fail to distinguish between added stearin and natural lards in themselves containing stearin in excessive quantities. Under such circumstances the decision as to the presence or not of an adulterant becomes a difficult one.

781. Vegetable Fats and Oils.—These have been already indicated, though very briefly, in the table given at an earlier stage of this chapter. But few of these are used alone, the most frequent employment of the oils being in conjunction with various animal fats. Among the solid vegetable fats are cacao-butter, which is the natural fat of cocoa or chocolate.

The so-called cocoa-nut oil is, in reality, not a liquid, but a solid, and is characterised by possessing a somewhat low melting-point, and yet being a rather hard fat. In its natural state this fat is said to readily become rancid: the thoroughly purified forms are certainly free from this very serious defect. In preparing these from the crude cocoa-nut fat, the fat is melted in a vacuum, and then a current of low pressure steam forced through. This latter carries off volatile substances of objectionable or pronounced odour or flavour, and leaves behind a pure and comparatively neutral fat. Like the lards, these preparations are pure fats, and contain no foreign matter. They are distinguished from other fats, both vegetable and animal (except butter), by possessing a rather high Reichert-Meissl value.

782. Margarine.—In 1870, the French chemist, Mége-Mouries, first described a method of making artificial butter on the large scale. Since then his methods have been considerably developed, and a large industry has grown up in what were formerly termed artificial butters, butterine, oleo-margarine, and now by legal enactment, "margarine." The basis of the modern methods of preparing this article consists in first rendering fat of the ox; this, after melting, is drawn off from solid impurities, and allowed to cool very slowly. During this process the more solid portion of the fat crystallises out as stearin, and is removed by filtration under pressure. The liquid portion solidifies into a granular solid of a slightly yellow colour, to which the name of "oleo" is given. Lard is also prepared in somewhat the same way, and to this the name of "neutral," or neutral lard, is applied. These two substances constitute the basis of margarine. The oleo being the harder fat of the two, is taken in larger quantity for margarine exposed to a warmer climate. The mixed oleo and neutral are next agitated with milk or cream, or possibly butter added, and thus the necessary flavour introduced. During the same operation, an amount of butter colour is incorporated, sufficient to produce a tint resembling that of butter itself. Different manufacturers use, in addition to these ingredients, various vegetable oils, in order to soften the products, and thus render them more adapted to general purposes. Arachis, cotton-seed, sesamé and other oils are thus employed. When properly made, there can be no doubt as to the wholesomeness and nutritive value of these artificial butters. The conditions of manufacture are usually hygienic, the materials being obtained in a fresh state and sterilised before use. The composition of margarine is shown in the last three analyses quoted in the table of butters before given. The fat value is generally high, while a clear line of distinction between these substances and butter is afforded by the low Reichert-Meissl and high butyro-refractometer values. The former, in the case of No. 24, falls below 1.0, while in the admixtures of margarine and butter the figures of 4.0 and 5.7 respectively were obtained. At one time mixtures were offered to confectioners stated to contain anything up to 40 per cent. of butter; now, by law, the proportion of butter permitted to be added to margarine is restricted to 10 per cent.

783. Other Compound Fats.—Compound lards are yet another form of mixed fats; these are sold both under that name and also at times as pure lards. Their basis is usually beef stearin, or whole beef fat, mixed with vegetable oil, generally cotton-seed oil. With these more or less lard may also be incorporated. As lard is generally checked by its iodine value, these mixtures, if intended as fraudulent lard substitutes, require to be made so that their iodine value is the same as pure lard.

784. Mineral "Fats."—It is not too much to say that both the animal and vegetable kingdoms have been thoroughly exploited in order to find fats for the confectioner. One may go a step further, and say that the mineral kingdom has also been laid under contribution. There is a class of bodies known as paraffins, the higher members of which are, when pure, white, solid, tasteless waxes. Then next, another substance has been prepared, known sometimes as soft paraffin, and also as vaseline. This latter, which is also tasteless and odourless, has a soft and semi-buttery consistency. Its physical nature is very like that of the fats generally, but it differs in that it is unattacked, even by strong alkalies, and so cannot be converted into soap. It is therefore matter for little surprise that vaseline, paraffin, and petroleum products generally, are entirely unassimilable by the human digestive system, and consequently absolutely devoid of nutritive value. When a person buys a cake, these mineral bodies are certainly not of the nature, substance and quality of the article demanded by such purchaser. While as food these substances are perfectly valueless, the authors are not aware of their possessing any positively harmful qualities. It would seem probable that, according to the extent to which flour and other bodies were saturated with paraffin, they would be protected from digestive action within the alimentary tract, and thus they would be rendered more difficult of digestion and of less food value.

Sweetening Ingredients.

785. Sugars.—The principal sweetening agents of the confectioner belong to a group of substances known as sugars, of which bodies an extended description has already been given in Chapter VI. The following are the most important of the various substances, containing one or more of the sugars, that are of service in confectionery.

786. Honey.—Among bodies which are naturally sweet, perhaps that best known is honey. Since this substance is collected and stored by bees, man, in even a most primitive state, was familiar with honey, and valued it because of its sweetness. It would seem that honey was once the staple sweetening agent of many peoples, being used for that purpose in this country, and also as a source of those beverages which require a sugar as their basis. Although collected by the bee, honey is naturally a vegetable product, and is obtained from flowers. Honey not only possesses sweetness, but also distinct and various flavours, due to certain odoriferous and flavouring matters present in the flowers from which it is derived. This natural form of sugar is still used by the confectioner, and is one of the principal ingredients in the sweet basis of nougat.

In composition, according to Allen, honey is a concentrated solution of glucose (dextrose) and fructose (lævulose) in water. At times there is also present a small quantity of sucrose. In addition, honey contains small quantities of wax, pollen, mineral matter, and traces of flavouring and bitter substances, and formic acid. The following are the results of analysis of a number of samples of honey by various observers:—

Glucose (Dextrose)	22.2	to	44.7	per cent.
Fructose (Lævulose)	32.1	,,	46.9	,,
Total Glucose and Fructose ..	61.4	,,	82.5	,,
Wax, Pollen, and Insoluble Matters	trace	,,	2.1	,,
Ash	0.02	,,	0.49	,,
Water expelled at 100° C. ..	12.4	,,	24.9	,,
Undetermined Matters	1.3	,,	10.8	,,

In the great majority of samples, the total glucose and fructose range from 70 to 80 per cent., the water from 17 to 20, and the ash from 0.10 to 0.25 per cent. Among adulterants of honey are found glucose syrup (confectioner's glucose), cane sugar, invert sugar, and molasses (golden syrup). Dextrin is not found in genuine honey.

787. Cane Sugar, Sucrose.—The earlier names given to the sugars were derived from the source of each particular sugar; but it is now well known that one and the same variety of sugar may be obtained from a number of substances. When, therefore, a sugar is named cane sugar, the name indicates not necessarily that the sugar in question is derived from the sugar-cane, but that it is sugar of precisely the same kind as that originally derived from that source. Cane sugar occurs not only in the juice of the sugar-cane, but also in certain roots, especially that of the beet, and in the sap of some trees, of which maple sugar is a familiar example. Various seeds, such as the almond, barley, and also fruits contain cane sugar. The process of manufacture consists first in expressing the juice whether of the cane or the beet, heating to boiling point, and then getting rid of various impurities by the addition of lime. To get rid of the colour, the solution of sugar is filtered through animal charcoal, after which the syrup is evaporated in steam-heated pans and finally *in vacuo*. Crops of crystals of sugar are thus obtained, leaving behind a residuum of syrup known as molasses.

The types of sugar used by the confectioner, such as sugar crystals, castor sugar, and pulverised sugar, are almost chemically pure. Moist sugar, or "pieces," contains water in varying quantities up to about 8 per cent. Various commercial sugars have the following percentage composition:—

COMPOSITION OF VARIOUS SUGARS.

Constituents.	Raw Cane Sugar.	Raw Beet Sugar.	Refined Sugar, Cane or Beet.
Sucrose	87 to 99	89 to 96	91.1 to 99.9
Glucose and Fructose ..	2 „ 9	trace „ 0.3	none „ trace
Ash	0.2 „ 2.3	1.6 „ 2.6	trace „ 0.15
Water	0.4 „ 6.8	2.0 „ 4.3	trace „ 0.25
Organic Matter not Sugar	0.3 „ 9.7	0.4 „ 4.0	none

So long as sugars are imperfectly refined, and not absolutely freed from the residual syrup, beet sugar is inferior in quality to that of the cane. But by modern processes, the sugar is obtained in what is essentially a chemically pure state; and in this condition sucrose, whether derived from the cane or the beet, is identical in character, and samples obtained from the two sources are undistinguishable from each other.

Refined sugars are now almost invariably "blued" in order to correct any slight yellowish tint. Minute traces of ultramarine, or other blue, are added for this purpose. Such an addition is usually regarded as harmless.

788. Molasses, Treacle, or Golden Syrup.—The residual juice of the sugar cane, before referred to, forms when concentrated a pleasant smelling and tasting syrup; therefore the molasses from cane sugar is agreeable to the taste. The concentrated beet juice contains, however, substances which are not pleasant in odour or taste, and therefore beet sugar molasses is not acceptable for food purposes. Here are given analyses of golden syrup and treacle, Nos. 1 and 2, by one of the authors, and 3 and 4 by Wallace.

COMPOSITION OF GOLDEN SYRUP AND TREACLE.

Constituents.	Golden Syrup.	Treacle.	Golden Syrup.	Treacle.
Cane Sugar	34.40	32.55	39.6	32.5
Glucose and Fructose	46.35	42.85	33.0	37.2
Water	18.50	15.20	22.7	23.4
Mineral Matter	0.75	9.40	2.5	3.5
Other Organic Matter			2.8	3.5
	100.00	100.00	100.6	100.1

789. Inversion of Cane Sugar.—The chemical changes involved in the inversion of cane sugar were explained in Chapter VIII., paragraph 276. As there stated, they result in the formation from one molecule of sucrose of a molecule each of glucose (dextrose) and fructose (lævulose). The following deals with the bearing of cane sugar inversion on certain processes of the confectioner. It may be of interest to mention that dextrose is found largely in the juice of grapes. When dried into raisins, these on becoming old develop gritty masses in their interior. These little lumps are aggregates of small crystals of dextrose, which at times is called grape sugar. The lævulose, so-called from its left-handed rotation, is now frequently termed fructose or fruit sugar, and crystallises only with great difficulty; hence its presence acts as a preventative of crystallisation. If a saturated cold solution of cane sugar be divided into two equal parts, and the one inverted by treatment with hydrochloric acid, the two may be placed away together for purposes of observation. Even though the unaltered sucrose have water added to it in the same volume as hydrochloric acid was added to the other moiety, yet as time proceeds the cane sugar crystallises rapidly. In such solutions thus made and set aside by the authors, the cane sugar had at the end of some three weeks become almost solid, while not a single crystal had developed in the solution of invert sugar. Not only is invert sugar itself singularly free from a tendency to crystallise, but its presence tends also to prevent crystallisation of cane sugar present in the same solution. Striking illustrations of this occur in the boiling of jams, where a solution of sugar is heated with fruit containing organic acids. In a sample of raspberry jam made in the authors' laboratory from cane sugar and fruit only, it was found, after keeping, that some 50 per cent. of the sugar had undergone inversion. As already mentioned, cane sugar, on heating, is changed into an amorphous variety; and hence the "glassy" type of sugar in such sweets as barley sugar. Still in these there is the tendency to crystallise, and such sweets would become opaque on being kept. To prevent this, acid is added during the boiling, and by the inversion of part at least of the sugar completely prevents, or very considerably retards, the process of crystallisation. Whenever sugar is inverted by acid during a process of sugar working, or invert sugar is introduced in a mixture, then the general effect is to retard or prevent crystallisation. Although invert sugar or glucose is thus almost continually being formed from many sugar-working processes, yet it is rarely if ever added or employed as a previously prepared product by the confectioner.

790. Comparative Sweetness of Cane and Invert Sugar.—When unripe fruit is used in the manufacture of pies and puddings, they are too sour to eat without the addition of sugar. Sugar may be added, and cooked with the fruit, or else subsequently at the moment of eating. Various opinions have been expressed as to the respective advantages of these two methods. When added previous to cooking, more or less of the sugar is inverted by the acids present, and the degree of sweetening action of the added sugar must evidently depend on the comparative sweetness of cane sugar, and the invert sugar produced therefrom. In order to throw light on this point, one of the authors made an experiment, in which a solution of cane sugar was divided into two equal parts, and the one moiety carefully inverted and neutralised, after which both were made up to the same volume. On being compared for taste by half-a-dozen persons, the general verdict was that, for initial taste, the cane sugar was, if anything, the sweeter. On the other hand, the sweetness of the invert sugar was much more persistent and lasting on the palate. Owing to this latter property, the invert sugar was, in its total effect, considered the sweeter of the two. In the next place, an attempt was made to decide which had the greater "covering power" for acids, and for this purpose each solution was acidulated with an equal quantity of dilute sulphuric acid, and again tasted. The acid flavour is very rapid in its effect on the palate; and consequently, the cane sugar which seemed to act on the palate with almost equal speed, mingled its sweetness with the taste of the acid, and so produced a homogeneous flavour. When the invert sugar was tried, the first sensation was one of overwhelming sourness, followed by the gradually accumulating sweetness of the slower but more lasting taste of sugar after inversion. The more preferable method of sweetening the fruit of pies and puddings would therefore seem to be that of adding the sugar subsequent to the cooking. But if the full advantage of the sugar thus added is to be derived, the sugar should be in a finely divided state, and allowed to dissolve in the juice of the fruit before being eaten. It is probable that the apparently greater sweetness of previously added sugar may be due to its having been thoroughly dissolved, as against the addition of large crystals of sugar after cooking, and their deglutition without solution. The question discussed throws an interesting side-light on problems of flavour generally. Much may be due to the selection of flavours which, when realised by the palate at the same time, shall conjointly produce a favourable impression; or if appreciated in succession, shall give a sequence of effects which is in itself pleasant. That the distinction is a real one, is evinced by the frequent discrimination of flavours into "taste" and "after-taste."

791. Sugar Boiling.—If the temperature of sugar be maintained for some time just a little above the melting point, the sugar is changed without loss of weight into a mixture of dextrose, and a substance called lævulosan, thus:—

$$\underset{\text{Sucrose.}}{C_{12}H_{22}O_{11}} = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Lævulosan.}}{C_6H_{10}O_5}.$$

Further application of heat causes water to be given off, with the probable conversion of the dextrose into glucosan, thus:—

$$\underset{\text{Dextrose.}}{C_6H_{12}O_6} = \underset{\text{Glucosan.}}{C_6H_{10}O_5} + \underset{\text{Water.}}{H_2O}.$$

At a yet higher temperature further decomposition ensues, both lævulosan and glucosan being converted into caramelan, $C_{12}H_{18}O_9$, thus:—

$$\underset{\substack{\text{Glucosan and}\\ \text{Lævulosan.}}}{2C_6H_{10}O_5} = \underset{\text{Caramelan.}}{C_{12}H_{16}O_9} + \underset{\text{Water.}}{H_2O}.$$

Caramelan when pure is colourless, has a slightly bitter taste, and is highly deliquescent.

Further elevation of temperature to from 374° F. (190° C.) to 410° F. (210° C.) results in the formation of so-called caramel, which is a mixture of dark-brown bodies, more or less soluble in water and alcohol.

This statement of the chemical changes occurring when sugar is subjected to the action of heat will serve as a prelude to a description of what is called "sugar-boiling" by the confectioner. This process is usually conducted in deep round copper pans, the size of which will naturally depend on the extent of the contemplated operations. These pans may be heated either by gas or direct fire heat. It is well to have an ample margin of sufficiency of heat, since rapid heating to a given point will produce results which differ from slowly raising the temperature to the same degree. The confectioner places in his pan say 7 lbs. of white cube sugar or crystallised sugar, and one quart of water. This is set on the fire and the contents raised to the boiling point: directly this occurs, the liquid is carefully stirred with a spatula, so as to dissolve any lumps of sugar which may happen to remain. At this stage the mixture is a solution of sugar in very hot water. On continuing the boiling a little longer, the temperature of the solution rises, and if taken by a thermometer, will be found to be at from 215 to 220° F. Each particular stage of temperature corresponds to a certain degree of sugar boiling, to which a technical name is given. Thus at the temperature of 215 to 220°, the degree of *smooth* is reached. The workman identifies these degrees by physical tests which he applies to the sugar. Thus he dips a clay pipe stem into the liquid, and draws it between the finger and thumb; at the *smooth* degree the sugar feels oily, and hence the name of the degree. Proceeding still further with the heating, a temperature of 230 to 235° is reached, and now the sugar is at the *thread* degree. During this time water has been driven off from the sugar, and now on cooling, the solution is sufficiently viscous to draw into *threads,* if a little is pulled out etween the finger and thumb. With further heating, a temperature of 40 to 245° is reached, and the sugar is in the *blow* or *feather* degree. t this stage the liquid has become so viscous that the steam generated n boiling *blows* the mass into huge bubbles, and in fact, may easily boil ver the pan. If a little of the sugar be tossed in the air, it will exhibit a *eathered* appearance. At 250 to 255°, we reach the *ball* or *pearl* deree, and a little of the sugar taken on a pipe stem or glass rod and ipped into water acquires a consistency about equal to that of putty. We ow proceed to carry our heating operation a considerable distance further, and when the thermometer registers from 310° to 316°, the sugar s at the *crack* degree. If now cooled in water, the sugar rapidly hardens nd becomes *brittle.* Very little further heating causes an incipient caraelising, and the confectioner's *caramel* degree is reached.

During these stages the water originally added is being driven off; hile toward the last the sugar is undergoing those successive steps of egradation towards caramelan, by "shedding" or losing molecule after olecule of water. It will be noticed that throughout, the sugar still etains the chemical composition of a carbohydrate.

792. Cutting the Grain.—At this stage an explanation must be given f what the confectioner terms "cutting the grain" of sugar. When eated above 250° F. the sugar will, if allowed to cool, crystallise into a ard granular mass. The sugar, in fact, re-solidifies from fusion and rystallises in so doing. To "cut" or destroy this graining tendency, the onfectioner employs some acid substance, that most frequently used eing cream of tartar, which is the acid tartrate of potash (hydrogen otassium tartrate). Instead of this, tartaric, citric, or acetic acids may e employed. The cutting agent may be added to the sugar when first ixed with water, and the whole heated together. Sugar thus treated, nstead of graining, remains pliable while hot, and transparent when cold. The sugar has in fact lost its crystalline nature, and has become an morphous or vitreous substance. From what has been previously exlained, it will at once be seen that cutting the grain consists of inverting ore or less of the sugar by means of an acid body.

793. Fondant Sugar.—This preparation is used both in flour and ugar confectionery. Sugar, water, and cream of tartar are first boiled to the feather degree. Then, in hand-working, the syrup is stirred until it becomes creamy through the production of minute crystals. On the large scale the same effect is obtained by pouring the requisitely boiled syrup into a vessel in which, during cooling, it is violently agitated by paddles or stirrers; crystallisation goes on, and the creamy mass of fine crystals, suspended in syrup, pours out from the lower end of the vessel. The crystalline portion of the fondant is simply unaltered cane sugar crystals, the softer and non-crystalline portion consists of invert sugar.

794. Starch-Sugar, "Glucose."—By processes already explained (paragraph 528) malt is converted into the preparation known as malt extract. Starch forms a much cheaper source of malt sugar or maltose, and may be changed into a mixture of maltose and dextrin by the action of diastase, or more conveniently by hydrolysis by dilute acid. But while diastase is incapable of carrying hydrolysis further than maltose, acids produce by further conversion more or less glucose. Starch sugar finds many uses, and consequently its production is an important branch of manufacture. Maize starch is that most commonly employed. The starch, water, and a small quantity of sulphuric acid, are heated together in large wooden vats by the introduction of steam. This operation is continued until a small portion of the liquid ceases to give the starch reaction with iodine. Chalk (calcium carbonate) is next added in slight excess, so as to neutralise the acid. The calcium sulphate is allowed to settle, and the upper liquid decolourised by filtration through animal charcoal, and concentrated by evaporation until the solution, when cold, has a specific gravity of about 1.3 to 1.4. Starch sugar thus obtained is a colourless, odourless, and transparent syrup, possessing a pleasant, sweet taste.

795. Analysis of "Glucose."—The following are analyses of malt extracts, for purposes of comparison, and commercial starch sugars:—

ANALYSES OF MALT EXTRACT AND "GLUCOSE."

Constituents.	Malt Extract. No. I.	Malt Extract. No. II.	Starch Sugar. No. I.	Starch Sugar. No. II.
Water	22.23	26.30	18.24	15.20
Mineral Matter	1.10	1.60	0.26	0.18
Proteins	3.01	5.40	—	—
Dextrin	12.90	7.65	16.00	16.20
Sucrose	3.59	4.07	—	—
Maltose	54.84	47.01	55.50	59.00
Dextrose and Lævulose (Glucose) ..	2.33	7.97	10.00	9.42
	100.00	100.00	100.00	100.00

The starch sugar, being made from the purified starch only, contains none of the ready-formed sugars of the grain, nor any proteins, such as are found in malt extract. The mineral matter consists of a trace of calcium sulphate held in solution in the syrup. The essential constituents of starch sugar are dextrin and maltose, which in the figures given in the first analysis, together form about 87 per cent. of the total solid matters present. The remainder is composed almost entirely of dextrin. Starch sugar has a remarkably high right-handed rotatory power on polarised light, the figure for the first sample quoted being 2.75° per gram of solids in 100 cubic centimetres of the solution when measured in a two-decimetre tube.

It will be seen, therefore, that starch sugar has about double the right-handed rotary power of cane sugar, which high figure absolutely differentiates it from invert sugar or glucose, with its left-handed rotary power. In the analysis quoted the high rotary power indicates that the proportion of glucose present (if any) must consist practically entirely of dextrose, or the right-handed variety of glucose.

In the preceding analyses of starch sugar, the dextrin was determined by direct precipitation. Subsequent investigations showed that in this body there were present considerable quantities of malto-dextrin (see paragraph 192). This needs a revision of the figures giving the results of analysis, which then become:—

Water			15.20
Mineral Matter			0.18
Dextrin			5.02
Malto-dextrin	Dextrin	7.32	11.18
	Maltose	3.86	
Maltose			68.42
Dextrose			nil
			100.00

If the conclusion based on the analysis of this sample be correct, the substance known as starch sugar may be viewed as essentially a mixture ot dextrin, malto-dextrin, and maltose.

With the well-marked composition of starch sugar it is to be regretted that the name used both popularly and commercially is a misnomer. Starch sugar is commonly called starch "glucose," whereas evidently a far better name is either starch sugar or, if preferred, "starch maltose."

Of the constituents of starch sugar it may be said that maltose, although a crystalline sugar, crystallises much less readily than does cane sugar. Dextrin, or as it is sometimes called, British gum, is a tasteless gummy body, which does not crystallise itself, and exercises an inhibitory action on the crystallisation of other sugars. Its use is, therefore, as a preventative of crystallisation; and in some goods starch sugar is employed, in order to prevent cane sugar crystallising, on much the same lines as a portion of the cane sugar is inverted by the addition of cream of tartar or other similar acid during sugar boiling. In addition to this, dextrin also seems to exercise a specific moisture-retaining effect, and the use of starch sugar is therefore indicated in those goods which are desired to retain a moist character.

FLAVOURING INGREDIENTS.

796. Fruit.—Fruit of various kinds is a most important flavouring agent in flour confectionery. Passing mention only need be made of the employment of fresh fruits in season; thus, gooseberries, currants, raspberries, cherries, plums, and apples, in their respective turns, are used in the manufacture of pies, tarts, and puddings. In chemical composition, most of the fruits consist largely of water, in next highest proportion containing carbohydrates, and lastly small quantities of other bodies, as set out in the following table, quoted from Hutchison's *Food and Dietetics*:—

	Per cent.
Water	85 to 90
Carbohydrates	5.5 to 10.5
Cellulose	2.5
Protein	0.5
Fat	0.5
Mineral Matters	0.5

The carbohydrates consist mostly of sugar, the principal one being lævulose, or fruit sugar, besides which there are varying amounts of cane sugar and dextrose. In addition to sugar, many fruits yield gum-like bodies, to which, as a group, the name of "pectin" has been given. In unripe fruits there is present an insoluble body known as pectose, which, by the action of a natural ferment, is converted into pectin. Pectin exists ready formed in ripe fruits, and also very largely in Irish moss. Pectin is soluble in water, and is devoid of any marked flavour and odour. Treatment with a small quantity of acid causes its solution to gelatinise. Like most other gelatinising substances, the power of this setting or "jellying" is seriously diminished, or even destroyed by long continued boiling of its solution. A solution of apple juice, on being concentrated, exhibits this jelly-like consistency in a very marked form, and apple jelly may be regarded as a pectin jelly sweetened by the addition of cane sugar.

Fruits contain notable quantities of various organic acids, among which are tartaric, citric, and malic acids. Cellulose is also present in more or less amount. In the act of ripening, the sugar of fruit increases in quantity, while the free acids diminish; at the same time, the cellulose also more or less disappears.

The characteristic flavour of different fruits is dependent on traces of various ethereal and allied bodies. Some of them have been identified and isolated, but many are present in such small quantities as to render their effectual examination impossible. When dealing with fruit essences reference will be made to some of these bodies.

797. **Dried Fruits.**—Certain kinds of fruit are more especially used in either the dried or otherwise prepared form. Most prominent among these is the ordinary dried currant of the grocer and confectioner. The currant is not a fruit of the same type as our fresh currant of this country, but is a small stoneless grape, which when dried in the sun constitutes the currant of commerce. The smaller raisin, known as a sultana, is also a dried grape of larger size than the currant. Both these owe their sweetness to crystallisable grape sugar or dextrose. Cherries are also prepared for somewhat similar use, by being stoned and then soaked in a concentrated solution of cane sugar. The following is the result of analysis of a good sample of currants, washed and dried, and sold as the best quality. The fruit was carefully hand-picked so as to ensure the absence of stones or grit before analysis.

	Per cent.
Water	23.24
Carbohydrates, principally Sugars	71.82
Cellulose	1.19
Proteins	1.67
Fat	0.10
Mineral Matters	1.98
	100.00
Energy in Calories	302.24

798. **Peel.**—A portion only of the fruits of the orange and lemon type is commonly used in confectionery, that portion being the peel. The peel of the orange, lemon, and citron are preserved by treatment with sugar syrup, then drained, and cut into slices. Peel largely owes its characteristic flavour to the essential oils found in that portion of the fruit, and to which reference will subsequently be made.

799. **Preserved Fruits.**—One obstacle to the regular use of fruit by the confectioner is that fresh fruit is in season for only a limited time of the year. To get over this difficulty, recourse is had to various methods of preservation. The simplest in principle is that of preserving the fruit itself without the addition of any other body. This object is effected by filling clean bottles with the whole fruit, and adding water to the neck. The bottles are then stood in tanks containing water at such a height as to submerge the whole of the bottle except the neck. The water is slowly heated until the boiling-point is reached. The bottles are then securely corked and capsuled, and if the operation be successfully performed, the contents are preserved indefinitely. To understand the principles involved in the preservation of fruit, it must be remembered that putrefaction and decomposition are due to the action of certain microscopic living organisms present on the surface of the fruit, and also pervading the atmosphere. If the life of these organisms be destroyed, then no putrefactive changes can occur in the fruit. The heat of boiling water is in this case found to be sufficient for the purpose. This preservation,

without sugar, results in maintaining the fruit in a condition approximating more closely to that of natural fruit than when foreign preservative agents are added.

800. Jam.—More usually, fruit is preserved in the form of jam, since the cooking, and also the addition of sugar, are, for many purposes, of advantage rather than otherwise. Jam may be defined as a "cooked confection of fruit to which has been added cane sugar or other wholesome sweetening and preservative agent or agents." The public demand that jam shall be palatable and also pleasing to the eye; further, that it shall be absolutely wholesome in character and contain nothing in the slightest degree deleterious. If it fulfil the whole of these conditions, it is difficult to see where the interest of the consumer is in any way furthered by limiting the range of constituents of jam any more than is done in the case of any other confection.

The busy time of the jam-maker is in the fruit season. Fruit, sugar, and if necessary a little water, are added together in a steam-jacketed copper pan fitted with a mechanical stirrer. High pressure steam is admitted to the jacket, the fruit and sugar thus boiled being continually stirred the whole of the time. The boiling having proceeded sufficiently far, the jam is poured out of the copper into a suitable vessel, and then conveyed away to the filling-room, where it is placed in jars or other convenient receptacles. In practice, it is found an advantage to make only a portion of the fruit into jam during the actual fruit season. Large quantities of fruit are simply converted into pulp by appropriate pulping machines, then boiled sufficiently to thoroughly sterilise and thus preserve the pulp. Such pulp is stored until required, when it is transferred to the boiling coppers, the requisite quantities of sugar added, and the jam boiled and prepared in the same manner as with fresh fruit.

The chemistry of jam-boiling follows lines already indicated in other manufacturing operations which have been described. Various kinds of jam must differ according to the character of the fruit, the differences largely depending on the degree of acidity of the fruit in question. During the act of boiling, such acid inverts more or less of the cane sugar added. As was fully explained during the treatment of sugar-boiling, invert sugar exercises an inhibitory action on the crystallisation of the cane sugar also present. Therefore, the inversion of cane sugar by the acid of the fruit prevents subsequent crystallisation of the jam. The less acid the fruit contains the less is the amount of such inversion. With very ripe and comparatively non-acid fruits the requisite amount of inversion may be obtained by prolonging the boiling, since the effect of a small quantity of acid acting for a longer time is much the same as that of a large quantity for a shorter time. But too prolonged boiling introduces another difficulty—the pectin in the jam, like other analogous substances, has its setting or "jellying" properties diminished or destroyed by too prolonged boiling, and therefore it is not always feasible or advisable to push inversion by a too prolonged boiling. In the case of sugar-boiling, an alternative method to the use of acid for "cutting the grain" was described, in which the prevention of granulation was due to the addition of starch sugar (or starch maltose). The jam manufacturer finds the same agent of service for the same purpose, and accordingly with some kinds of fruit, and under certain conditions, a portion of the sugar used consists of that from starch. The maltose crystallises less readily than does cane sugar, and in this way lessens the tendency to crystallisation. But the dextrin also present in starch sugar is probably a yet more effective preventative, and exercises a very powerful retarding influence on the crystallisation of the jam. In those kinds of jam prepared from acid fruits, no addition of starch sugar is necessary. When very acid-free fruits are employed, the addition of starch-sugar is an advantage, and in no way lessens the palatability or wholesomeness of the jam. Recently some preparations of marmalade have been put on the market, in which the slices of fruit float in a thick, transparent, sirupy jelly. These forms appeal very strongly to the eye and also to the palate; in their manufacture starch sugar is almost a necessity.

In jam-making, the boiling itself is a very efficient agent of preservation; but the sugar also acts as a preservative agent, since although dilute sugar solutions ferment readily, yet sugar in this concentrated form is a powerful antiseptic body.

Among things to be condemned without reserve in the manufacture of jam is the use of unsound or decomposed fruit, and also that of low grade and impure sugars, whether of the sucrose or maltose variety. These lower the quality of the jams, and render them decidedly unwholesome. Well-made jam does not require the addition of formalin, salicylic acid, or other similar preservatives. The addition of artificial colouring matter is also unnecessary, although with modern harmless colours, no actual injury results from their employment.

Jam for confectioners' purposes requires to be made of such a consistency that it will readily stand the heat of cooking in tarts, etc., without becoming so liquid as to run out. This point is a very important one, and hence specially stiff jams are manufactured for use in confectionery. The purchaser of jam is warned against jams containing one particular adulterant, agar-agar, or Japanese isinglass. The essential constituent of this substance is gelose, a compound consisting of carbon 42.77, hydrogen 5.77, and oxygen 51.45 per cent. Gelose has remarkable gelatinising power, and one part in 500 of water will set to a jelly. The addition of this substance to jams enables them to carry an excessive quantity of water and yet to be of firm consistency. But such jams become exceedingly fluid on the application of heat, and run out of any goods in which they are used in the act of baking.

801. Nuts.—Nuts are characterised by the high proportion of oil or fat which they contain; this amounts to from 50 to 60 per cent. of the whole nut, the remainder consisting of protein, carbohydrate in small quantities, and cellulose. The oil of nuts is likely to become rancid on keeping; for this reason walnuts and other nuts are liable to acquire an unpleasant taste if exposed to the air. Almonds are supplied not only as the whole kernel of the nut, but also in a ground condition. In this latter form there is opportunity of considerable sophistication. Buyers of ground almonds should be on their guard against removal of oil, and addition of starch, sugar, or other foreign matters. The cocoa-nut is also largely used for confectioners' purpose. The nut, after removal from the shell, has the outer skin pared off; the flesh of the nut is then shredded and carefully dried. Again the purchaser should satisfy himself that no oil has been removed.

802. Essential Oils.—In the case of a very large number of substances, their special and peculiar flavouring qualities are due to the presence of small quantities of substances possessing the particular taste and smell in a marked degree. These flavouring matters have, in many cases, been isolated and obtained in a state of purity. In a large number of instances their physical properties are those of a volatile oil; that is to say, they are liquid, more or less oily in their nature, evolve a distinct and often powerful odour at ordinary temperatures, and boil or distil at a much lower temperature than the common or fixed oils.

803. Oil of Peppermint.—This substance is prepared from the plant known as peppermint. The herb is cut and soaked in water in the boiler part of the well-known still; heat is applied and as the water boils, its steam carries along with it the vapour of the essential oil of peppermint. The steam is condensed, and the resultant water is found to be charged with the odour and taste of peppermint in a much more concentrated form than in the plant itself. In this way was made the old-fashioned housewife's "peppermint water." But with this operation of distillation properly conducted on large quantities of peppermint, the distilled peppermint water is found to contain an oil which rises to the surface, and may then be separated. On these principles are prepared commercial oil of peppermint, and the manufacture of this oil may be taken as a type of that of many other essential oils.

In composition this oil consists largely of the substance termed menthol, which is a crystallisable solid, melting at 42° C., and an alcohol in chemical composition. This body in its free state is a well-known article, and is simply obtained by freezing the oil, when menthol separates in the solid form, and is purified from the still liquid adherent oil by pressure, or drying in a centrifugal machine. This de-mentholised oil is either sold as such, or used as an adulterant of the oil itself. Another form of adulteration is the addition of either wood turpentine or other bodies of the terpene group.

804. Analysis of Essential Oils.—Substances commanding such a high price as essential oils offer peculiar and special temptations to the adulterator, hence their composition should be checked by analysis. The following is an outline of the principles involved in such examination:—

I. Essential oils have a fairly definite specific gravity varying for the one oil with well-defined limits.

II. Many oils exercise a rotary power on polarised light; consequently, like the sugars, essential oils are examined by the polarimeter. It is usual to express the results in degrees of dextro- or lævo-rotation when measured in a decimetre tube.

III. The boiling point of essential oils is fairly constant for the same oil, and so the temperature of the boiling point is also determined.

IV. The oil may contain some special compound on which its value largely depends. If this compound can be readily estimated with accuracy, such determination is an important guide in the commercial valuation and determination of purity of the oil.

Applying these principles to oil of peppermint, the following are the requirements of this oil:—

I. *Specific Gravity,* 0.900 to 0.920 at 15.5° C.

II. *Optical Rotation,* Lævo-rotary, —20 to —30°.

III. *Boiling Point.* The oil should not boil below 200° C., but should distil almost completely between 200° and 215° C.

IV. The menthol in the oil may be determined approximately by cooling the oil by means of a freezing mixture, and then introducing a small crystal of menthol. If the oil has been de-mentholised it remains more or less liquid, but if pure, it forms a crystallised mass through separation of solid menthol. This test is preferably replaced by an estimation of menthol by purely chemical methods.

805. Essential Oil of Lemon.—This oil is of vast importance to the confectioner, and is well known as a light yellow liquid of extremely fragrant odour. Unlike peppermint oil, that of lemon is not usually obtained by a process of distillation. The essential oil resides in small cells immediately below the outer surface of the lemon, and these are burst on bending the peel. For many cookery purposes, the flavouring matter is obtained by grating off the outer layer of the skin, which grating is then known as the "zest" of the lemon. The process of manufacture is conducted on similar principles. The interior of the lemon is first removed, leaving its rind in two cups; these are turned inside out, and the ejected essence wiped off the originally outer surface by a sponge. This operation is continued until the sponge is saturated, when the oil is squeezed out into a vessel, and the collecting operation continued.

In composition, oil of lemon consists principally of a terpene, having an analogous composition to that of wood-turpentine, and to which the names of lemon-terpene and limonene have been given. This body differs from turpentine in that it possesses a higher boiling point and a higher rotary power than the latter. As a flavouring agent the terpene of lemon oil is comparatively of little value, the essential flavouring matter being an aldehyde, $C_{10}H_{16}O$, known generally as citral. Oil of lemon contains citral in quantities varying from 4 to 7 per cent. For some purposes the presence of the lemon terpene is considered an objection, and, therefore, there are at present put on the market so-called terpeneless oils of lemon in which all or part of the terpene has been removed, and the citral with other flavouring ingredients alone remains. Such oils are prepared by a process of distillation *in vacuo*; the terpenes, having a lower boiling point, first distil over and leave behind the citral residue.

Like the other oils, there are certain requirements which that of lemon are expected to fulfil; of these the following is a summary:—

I. *Specific Gravity.* 0.857 to 0.860.

I. *Optical Rotation.* Not below + 59°.

III. *Boiling Point.* Not below 170°.

IV. On being subjected to fractional distillation, the first 10 per cent. distilled over will exhibit a less optical rotation than that of the original oil, but such difference should not exceed two degrees. This last limit is that laid down by the *British Pharmacopœia*, but the amount of such differences varies considerably in different years. A fairer figure for general use is 3.0°, and this is the limit adopted by Parry. Thus recently examined oil of undoubted purity gave the following figures:—

Optical rotation for whole oil	+ 62.5°
Optical rotation of first 10 per cent. of distillate ..	+ 57.4°
Difference	5.1°

Oils of lemon are frequently sold with the results of a direct estimation of citral given; but, for several reasons, this is no very true guide to value. In the first place, the results obtained by the rougher methods of estimating citral may be far from accurate, and an investigation of the methods of sophistication indicate other and more cogent reasons for distrusting citral estimations as an indication of actual value.

806. Adulteration of Oil of Lemon.—In earlier days, the principal adulterant of oil of lemon was turpentine, and even now samples are at times met with containing some 40 or 50 per cent. of this body. The limitations previously given will readily serve to detect adulteration with oil of turpentine, since this body has an optical rotation of from —40° to +20° according to source, and a boiling point of about 157°. Any large admixture of turpentine will lower the optical rotation of oil of lemon, but this can be to some extent masked by the addition of cheap oil of orange, which has a rotation of from +92 to 98°. By boiling and fractionally distilling, the presence of turpentine is clearly revealed. First, it lowers the boiling point; and, secondly, the first fraction of distillate will have a much lower optical rotation, since the terpenes of either oil of lemon or oil of orange agree very nearly with the original oils in rotary power. It is for this reason that the limit of 3° has been laid down, although, as first stated, this is not sufficiently elastic to include all pure oils. But when a difference of as much as 12 or even 15 degrees occurs, as was the case in some samples examined, which had been recently sold by well-known firms, then evidently the buyer is being subjected to a fraud of a very marked kind. But the use of oil of turpentine is now largely superseded by adulteration of a much more insidious description. In the manufacture of terpeneless oil of lemon, lemon terpenes are largely produced as a waste product. As such terpenes constitute some 93-95 per cent. of pure oil of lemon, it will be seen that their addition cannot, very largely, alter the chemical constitution of the oil, except by lessening the proportion of the (approximately 5-6 per cent. fraction of) citral and allied constituents. Neither the boiling point nor the optical rotation of the oil is thus affected; and further, the first 10 per cent. of distillate will also agree with the standard tests. There remains the direct estimation of citral, but unfortunately, from the present point of view, oil of lemon is not the only source of citral. Verbena, or as sometimes called "lemon plant," and also lemon grass, yields oils which contain about 80 per cent. of citral, and consequently lemon grass oil forms a comparatively very cheap source of citral. A mixture of say 94 parts of lemon terpene with 6 of lemon grass oil, will answer not only to the B.P. (*British Pharmacopœia*) limitations before quoted, but also to a direct citral estimation. Therefore, the simultaneous addition of lemon grass oil as well as lemon terpenes to oil of lemon evades both the B.P. tests, and also a direct citral determination. But although such a mixture may answer to the tests mentioned, it is in no way a true or efficient practical substitute for pure oil of lemon. Oil of lemon contains other odoriferous constituents than citral, which latter are not furnished by lemon grass oil; and this oil contains odorous and flavouring matters which are foreign to oil of lemon. The presence of lemon grass oil is revealed by the odour of verbena possessed by the oil, and this can fairly readily be detected by the expert. A considerable assistance in applying the "nose test" to lemon oil is to have it distilled *in vacuo* to 10 per cent. of the original volume, and then smell the concentrated citral, etc., residue either in its normal condition or after dilution with pure concentrated alcohol. In the absence of the terpenes the nose can often better judge the character, origin, and quality of the essential flavouring bodies present. When making an analysis of oil of lemon it is no very difficult matter for the chemist to return this concentrated residue of distillation to his client, and allow him to exercise his own judgment on its odorous qualities. Nobody can feel more strongly than chemists the urgent necessity for buying oil of lemon only on analysis; but failing this very obvious precaution, the buyer may generally take it for granted, that given a range of oils supplied by one and the same dealer, he will get as good (if not the best) value for his money by selecting oils of the top quality, as by taking those of lower price. If he has a preference for diluted oils, the most economic method of gratifying it is by buying pure oil, and lemon terpene, and mixing them at his own discretion.

807. Essential Oil of Orange.—This oil like that of lemon is prepared from the rind of the fruit. In commerce there are two varieties, the oils of sweet and bitter orange. Pure orange oil has a specific gravity of 0.848 to 0.856. The optical rotation of these oils is very high, usually falling between +94° and +98°. The oil commences to boil at 173° to 174°. As with the oil of lemon adulteration is practised by the addition of waste terpenes of oils of orange and lemon.

808. Orange Flower Water.—An odoriferous and flavouring agent is also contained in the flowers of the orange, and is extracted by adding water to the petals of the flower and then distilling. The resultant distillate contains an essential oil known as oil of neroli. When the distillate is sufficiently concentrated this oil floats on the surface and is separated. The watery portion owes its flavour and odour to the fact that it holds a trace of the essential oil in solution, and is termed orange flower water.

809. Essential Oil of Almonds.—Almonds not only contain a true and non-volatile oil, but also a substance called amygdalin, which by taking up water, is converted into dextrose, essential oil of almonds, and hydrocyanic acid. The essential oil is obtained by a process of distillation, and is then freed by appropriate processes from the hydrocyanic acid. Such volatile oil of almonds is essentially benzaldehyde, C_7H_6O, and has a pungent characteristic odour. This oil is employed to fortify almond confectionery, a less proportion of almonds being used, and a larger portion of sugar or other sweet bodies employed. In ground almonds, as supplied ready-made to the confectioner, this type of adulteration should be carefully watched for. It is only within certain limits that this employment of essential oil is advisable, since its too generous use gives a strong over-powering flavour, markedly different from the delicate taste of the almond itself. Pure natural oil of almonds, freed from hydrocyanic (prussic) acid, used to be worth from 25*s.* to 30*s.* per lb., while inferior oils and fraudulent and poisonous substitutes ranged at the same time in price from 20*s.* to as low as 6*d.* per lb.

Benzaldehyde is manufactured on the large scale, and is found on the market as "artificial oil of almonds." This substance is used as a cheap perfuming agent, but its odour is not sufficiently delicate to permit of its being used in the highest class of perfumery, to say nothing of confectionery.

Oil of Mirbane is sometimes employed as an adulterant of oil of almonds, and chemically consists of nitrobenzene, $C_6H_5NO_2$, mixed with various impurities. It has a coarse almond-like odour, and is poisonous when taken internally. Comparatively recently a fatal case of poisoning occurred through oil of mirbane being mistaken for oil of almonds.

810. Other Essential Oils.—These must be passed over with but the slightest reference. The various spices, allspice or pimento, cinnamon, cloves, etc., all yield essential oils, and these are in many ways of use to the confectioner. Among the spice oils the most important are that of allspice or pimento, and oil of cloves. These are somewhat similar in character, and both contain a phenol known as eugenol. In oil of cloves the eugenol amounts to as much as from 85 to 90 per cent. The oil should have a specific gravity of 1.048 to 1.065, and a slight left-handed optical rotation, never more than — 1.5° and usually under — 1.0°. In pimento oil the specific gravity should not fall below 1.040, and the optical rotation is usually about —2°, and should never exceed —4°.

These oils already dealt with may be taken as types, and for particulars of others, systematic treatises, such as Parry's *Essential Oils,* must be consulted.

811. Essences.—There is a more or less subtle distinction between essential oils and essences. Thus, essence of lemon is not necessarily the same as essential oil of lemon. Many essences are solutions of essential oils and other flavouring ingredients in alcohol. An illustration of these is offered by the well-known essence of mixed spice of the confectioner, and used largely in the manufacture of "Hot-cross Bun." The real flavouring matter of such essence is a mixture of essential oils of different kinds of spice; but many samples also contain alcohol in large quantities running up in some cases to as much as 80 per cent. (and in extreme instances 90 per cent.) of the total essence. Samples such as these are now, however, of great rarity. With the increased duty on spirits, the oils themselves are frequently but little dearer than the alcohol. Such essences now frequently consist of a mixture of the essential oils with lemon or orange terpenes. As diluting agents these bodies are quite as suitable as alcohol.

Essential oils and essences require constant supervision, and all users of any but the very smallest quantities, will find their frequent analysis to amply repay them.

812. Fruit Essences.—The composition of fruits has been already discussed, but as their flavouring matters are prepared in a more or less concentrated form, they require some attention under this section of our subject. There is a small class of fruits of which the flavouring matter has been identified as largely composed of one or more definite chemical compounds. Thus as already explained, the essential oil of bitter almond consists of, and is identical with, benzaldehyde. The following are other instances of chemical compounds which are the source of the flavour of fruits:—

Fruit.	Flavouring Compounds.
Jargonelle Pear	Amyl acetate.
Quince	Ethyl pelargonate.
Pine-apple	Ethyl butyrate.

By this is meant, not merely for example, that the flavour of the jargonelle pear is simulated by acetate of amyl, but that that substance is the actual flavouring body of the pear itself. For these and possibly one or two other bodies, the essential flavouring ingredients are thus obtained in a pure form from outside sources; and what is sold as essence of jargonelle pear is largely, if not entirely, amyl acetate in a more or less concentrated condition.

Another group of essences consists of those of an artificial nature, built up from a number of essential oils and other flavouring ingredients, according to each particular manufacturer's recipe. Some of these are pleasant in flavour, and others the reverse; but whether pleasant or unpleasant, most of them bear but a very distant resemblance to the fruit they are supposed to imitate.

Manufacturing chemists have devoted considerable attention to the problem of conserving the natural essences of fruits in a concentrated and permanent form, and these efforts have met with considerable success. It would be impossible to attempt here any description of the manufacturing processes; but it may be said that the raw material is fresh ripe fruit. If one takes the most luscious fruit imaginable, its water, cellulose, proteins, fat, and mineral matter do not materially, if at all, contribute to the flavour. The pectin-like bodies are also flavourless, while the sugars, although sweet, are not distinctively flavouring. As these constitute the main proportions of the fruit, it is evident that a considerable concentration of the flavouring portion is conceivable, and, as a matter of fact, the solid portion of the fruit can be removed as an almost tasteless mass. It remains to drive off as much of the water as practicable, so as to obtain a strong solution of those constituents to which belong the characteristic taste. This being done, the fluid is sterilised so as to preserve it from decomposition, and, as a result, there is the purely natural essences of the fruits.

813. Vanilla and Vanillin.—Turning to yet another distinctly different type of flavouring matters, there may be taken as an example the well-known vanilla flavour. This flavour is familiar as a result of its presence in chocolate, ices, and other confections. The actual source is the pod or fruit of the vanilla plant. Close inspection of these pods shows them to be covered with a white efflorescence; this consists of the essential principle of vanilla, which has exuded and crystallised. To this body the name of vanillin has been given. Vanillin constitutes about 2 per cent. of the pod, and like many other flavouring and odoriferous substances is an aldehyde in composition. To obtain the flavour of vanilla in the most thorough and efficient manner there is probably no simpler method than to powder the pods themselves with sugar as a diluent, say 1 part of vanilla to 9 parts of sugar. The objection to this is that in light-coloured cakes and ices the appearance of what look not unlike particles of snuff scattered throughout the substance is unsightly. To obviate this, a tincture or essence of vanilla may be prepared by macerating the vanilla in alcohol and filtering off from the insoluble matter. The soltuion thus obtained yields all the flavouring bodies of the pods without the presence of the objectionable solid portion.

814. Synthetic Vanillin.—Vanillin is one of those substances which have been artificially prepared, the process usually adopted being that of subjecting eugenol, the essential constituent of oil of cloves, to a process of oxidation. When thus prepared and thoroughly purified, vanillin consists of a white crystalline matter of an intense vanilla odour. It is important that the vanillin should be thoroughly freed from the oil of cloves from which manufactured, or else the substance is liable to have itself a distinct odour and taste of cloves. When first put on the market vanillin commanded a very high price, and in 1876 was quoted at £160 per lb., while in 1898 the price had fallen to £2 12*s.* for the same weight. Vanillin is liable to adulteration with various harmless but valueless substances, the presence or absence of which can be determined by analysis. The manufacturers point out that a mixture of 2½ per cent. of vanillin in sugar is equivalent in strength to the vanilla pod itself. As the equivalent of the confectioner's "vanilla sugar," they recommend that 2½ per cent. vanillin sugar should be taken in the same quantity as would be taken of actual vanilla. Vanillin forms a very useful substitute for vanilla, and from its greater cheapness is somewhat extensively used. It is doubtful, however, whether for the most delicate flavouring purposes it can be considered a *complete* substitute for true vanilla. While undoubtedly vanillin is the chief and predominant flavouring ingredient of vanilla, yet it is probable that there are traces of other flavouring matters present, and the flavour of the pod is therefore that of vanillin, *plus* such additional flavours as are given by these other bodies, which are absent in artificial or synthetic vanillin.

Reverting a moment to the essence of vanilla, while the best is prepared from fresh pods, inferior qualities consist of tinctures made from the almost exhausted residue, which are subsequently fortified by the addition of artificial vanillin.

815. **Confectioner's Perfumes.**—Not only are flavouring matters employed by the confectioner, but he also finds a use for bodies which are ordinarily regarded as scents or perfumes only. Among these the otto of roses, and musk, find a place in the store rooms of the larger manufacturing confectioners. They, like the essences, are bodies whose chemistry possesses an intense interest, but in common with many other topics must perforce be excluded from the present review of confectioners' materials.

816. **Colouring Matters.**—The confectioner uses colouring matters for two distinct purposes. The one is to give a richer colour to confections which are comparatively colourless; the second is the use of colour for purely decorative purposes.

817. **Egg Colours.**—Cakes which are made with few or no eggs lack the rich yellow tint produced by eggs unsparingly used. To compensate for this, artificial egg colouring matter is frequently employed. For this purpose vegetable yellows may be employed; and in fact, in the west of England the saffron bun is a well-known and popular institution. Not only is saffron here used as a colouring matter, but also as a flavouring agent, for such saffron buns have a distinct taste of their own, which is entirely lost if the saffron be omitted. Other vegetable colours are also used; but the greater number of egg yellows and egg colourings offered to the confectioner belong to the group known popularly as aniline colours. Some time ago the authors examined a large number of so-called egg-yellow colourings, including practically every make of importance on the market; and among other things investigated their tinctorial power weight for weight, and price for price. In tinctorial power, as against unit weight, the most intense colour was about 180 times as strong as the weakest. In the matter of cost for the same amount of colour, some samples were just 30 times as expensive as others. On being tested for arsenic, the great majority of these colours were absolutely pure; some one or two, however, gave a sufficient arsenic reaction to make their use inadvisable. When it is remembered that these colours are offered at prices of from 1*s.* to 10*s.* 6*d.* per lb., it will be seen that accurate scientific valuation becomes a matter of importance.

818. **Decorative Colours.**—The most familiar example of the use of colours for decorative purposes is that of the tinted sugars employed for covering the tops of birthday and similar cakes. The colours used are soluble and are blended with the mixture of sugar and white of eggs while in the pasty state. Such colours should not be altered by traces of acid, since acetic acid in small quantity is generally used in making up icing sugar. Preferably, they should also be unaffected by weak alkalies as sodium carbonate. The principles which underlie the blending of colours for artistic effect lies outside the scope of the present work.

819. **Harmless and Injurious Colours.**—Certain colouring matters are generally recognised as harmless, while others must be regarded as doubtful, and some as decidedly injurious.

Harmless Colours.—Among the first or harmless group are, with some few exceptions, all organic colours obtained from the vegetable and animal kingdoms. To these are usually added the various aniline colours so long as they are pure and contain no arsenic. The examples most frequently found among confectioners' colours are:—

Red.—Cochineal, carmine, the juice of beet and red berries.
Yellow.—Saffron, safflower, turmeric, marigold.
Blue.—Indigo, litmus, saffron blue.
Green.—Spinach juice.
Brown, various shades of.—Caramel (burnt sugar).
Also various aniline colours.

Doubtful and Injurious Colours.—A few of these, such as picric acid and gamboge, are of organic derivation. They are mostly, however, of mineral origin, and may contain mercury, lead, copper, arsenic, chromium, and zinc. The following are specific examples:—

Yellows.—Barium chromate, and compounds of lead, arsenic, and antimony.

Greens.—Compounds of arsenic, and copper.

Blue.—Prussian blue.

820. Legal Enactments as to Colours.—In various countries laws have been passed defining exactly such colours as may and may not be used. Thus as early as February, 1891, the Official Municipal Bulletin of the city of Paris contained the following regulations:—

Paris Ordinance, 1890.—"Ordinance concerning the colouration of alimentary substances.

Article 1.—The employment of the colours herein after designated is forbidden for the colouration of all substances entering into articles of food.

MINERAL COLOURS.

Composed of copper.—Blue dust (cendres bleues), mountain blue.

Composed of lead.—Massicot, Minium or red lead, litharge. Carbonate of lead (white lead). Oxychloride of lead (Cassel's yellow, Turner's yellow, Paris yellow). Antimoniate of lead (Naples yellow). Sulphate of lead. Chromates of lead (chrome yellow, Cologne yellow).

Chromate of barium.—Ultramarine yellow.

Composed of arsenic.—Arsenite of copper, Scheele's green, Schweinfurt green.

Sulphide of mercury.—Vermilion.

ORGANIC COLOURS.

Gamboge.—Aconit Napel.

Colouring matters derived from coal-tar, such as fuchsine, Lyons blue, methylene blue; phthaleins and their derivations; eosin, erythrosin.

Colouring matters containing among their constituents nitrous gases, such as naphthol yellow, Victoria yellow.

Colouring matters prepared by the aid of diazo compounds, such as tropeolins, xylidin reds.

Article 2.—It is permitted to use for the colouration of sweets and other food substances the following coal-tar colours, because of their restricted employment, and the very small quantity of the colouring substances which these products contain:—

Red colours:

Eosin.

Erythrosin (methyl and ethyl derivations of eosin).

Bengal red, ploxine (iodine and bromine derivations of fluorescin).

Bordeaux reds, ponceau.

Acid fuchsin (without arsenic and prepared by Coupier's process).

Yellow colours:

Acid yellow, etc.

Blue colours:

Lyons blue, light blue, Coupier's blue (derived from triphenyl rosaniline or from diphenylamine).

Green colours:

Mixtures of the above blues and yellows.

Malachite green.

Violet colour:

Paris violet or methylaniline violet."

American Regulations, 1907.—Food Inspection Decision 76 of the United States Department of Agriculture makes the following regulations for the employment of colouring matters in articles of food:—

"The use in food for any purpose of any mineral dye or any coal-tar dye, except those coal-tar dyes hereinafter listed, will be grounds for prosecution. Pending further investigations now under way and the announcement thereof, the coal-tar dyes hereinafter named, made specifically for use in foods, and which bear a guarantee from the manufacturer that they are free from subsidiary products and represent the actual substance the name of which they bear, may be used in foods. In every case a certificate that the dye in question has been tested by competent experts and found to be free from harmful constituents must be filed with the Secretary of Agriculture and approved by him.

The following coal-tar dyes which may be used in this manner are given numbers, the numbers preceding the names referring to the number of the dye in question as listed in A. G. Green's edition of the *Schultz-Julius Systematic Survey of the Organic Colouring Matters,* published in 1904.

The list is as follows:—

Red shades:

107. Amaranth.
56. Ponceau 3 R.
517. Erythrosin.

Orange shade:

85. Orange I.

Yellow shade:

4. Naphthol yellow S.

Green shade:

435. Light green S. F., yellowish.

Blue shade:

692. Indigo disulphoacid.

Each of these colours shall be free from any colouring matter other than the one specified and shall not contain any contamination due to imperfect or incomplete manufacture."

THE END.

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